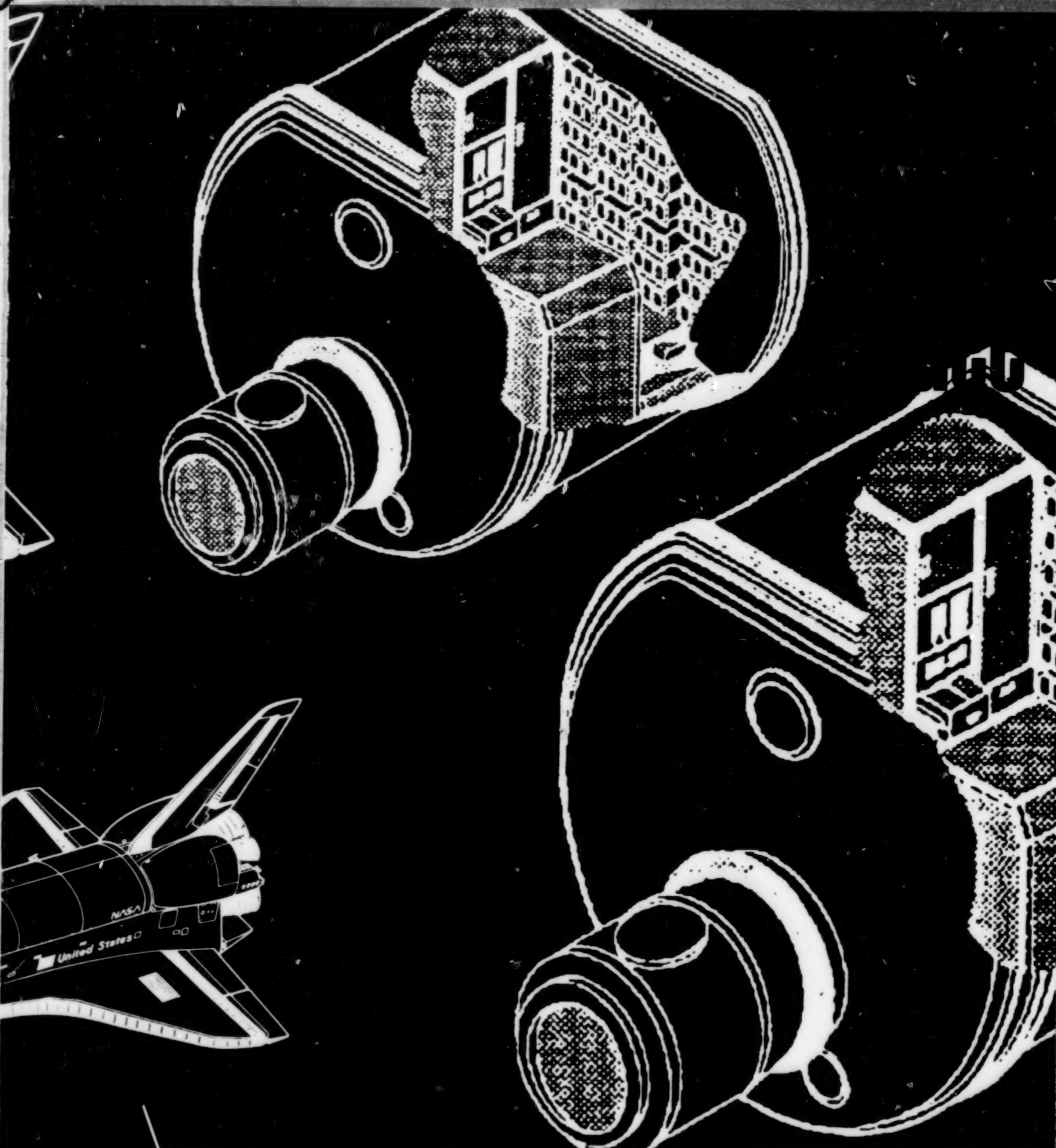


A Catalogue of Process, Equipment and Resources for Commercial Users 1990

(NASA-NP-133) ACCESSING SPACE: A CATALOGUE OF PROCESS, EQUIPMENT AND RESOURCES FOR COMMERCIAL USERS, 1990 (NASA) 270 p
N92-14963
CSCL 05B
Unclas
H1/99 0045773

Accessing Space: A Catalogue of Process, Equipment and Resources for Commercial Users

NASA
National Aeronautics and Space Administration

Office of Commercial Programs
Commercial Development Division

December 1990

Accessing Space: A Catalogue of Process, Equipment and Resources for Commercial Users was produced by the Futron Corporation under contract to the NASA Office of Commercial Programs and published by the Commercial Development Division.

The objective of this catalogue is to provide information to commercial developers of space. Publication herein does not constitute NASA endorsement of the products or services described, nor confirmation of the manufacturers' or providers' performance claims.

This catalogue represents a growing inventory of items and information brought to NASA's attention and is not to be considered all-inclusive or representative of comparative selection. Periodic revisions are planned to include additions or updates. Comments, corrections or submissions should be directed to:

Accessing Space Catalogue
Office of Commercial Programs
NASA Headquarters, Code CCL
Washington, DC 20546

December 1990

NP-133

Acknowledgements

Writer/Editor – Paula Korn
Design/Production – Tina Lindberg
Research – Ronya McMillen
Technical Review – C. H. Underwood

Foreword

Welcome to the second edition of **Accessing Space**, a publication created to assist U.S. developers of commercial space.

NASA's Office of Commercial Programs is committed to enabling the success of the commercial space ventures of the United States. NASA helps U.S. private firms by stimulating and facilitating the investigation of the unique environment of space, and the investment in and utilization of space activities. Through continuing support to industry, NASA is fostering U.S. leadership in commercial space endeavors and creating new industries that contribute to America's economy and its competitive position in the world market. More importantly, we believe these activities truly accelerate the exploration and utilization of space for the benefit of all mankind. Toward this end, industry teamwork with government is an essential ingredient for success.

This nation, in its government and industry space programs, has made significant investments in space research and development. We have developed an extensive network of centers, installations and ground-based laboratories as well as space-based facilities and unique experiment systems. A major part of these facilities and equipment is now available to the private sector. This catalogue serves an important role in disseminating useful information about such capabilities plus related information.

We are pleased to present the 1990 edition of **Accessing Space** and encourage your review of the broad resources it presents. As you explore the unique characteristics of space and its commercial potential, we welcome you as an entrepreneurial pioneer on the space frontier.

James T. Rose
Assistant Administrator
Office of Commercial Programs
NASA Headquarters
Washington, DC

Introduction to Accessing Space

This catalogue is intended for commercial developers who are considering, or who have in process, a project involving the microgravity environment of space or remote sensing of the Earth. A review of this publication should give the reader both an orientation to commercial space activities and a current inventory of equipment, apparatus, carriers, vehicles, resources and services available from NASA, other government agencies and U.S. industry.

The information presented here describes the array of resources that commercial users should consider when planning ground- or space-based developments. Many items listed in the catalogue have flown in space or been tested in laboratories and aboard aircraft and can be reused, revitalized or adapted to suit specific requirements. Other facilities and equipment are still in the development process.

New commercial ventures are encouraged to exploit existing inventory and expertise to the greatest extent possible. While utilizing commercial space is a complex business, NASA and industry have built a strong foundation for exploration and development. This catalogue is made available to commercial developers to facilitate their entry into space business.

In this second edition, we have responded to our readers' comments, refining our data extensively. We always welcome new thoughts and suggestions. The commercial space community is growing and emerging with the help of industrial and academic laboratories. By providing data on your projects, this document will continue to serve as a valuable means of information interchange within the commercial space community.

Richard H. Ott
Director, Commercial Development Division
Office of Commercial Programs

PRECEDING PAGE BLANK NOT FILMED

Table of Contents

Section One: The Process

Space offers special aspects and environments that may be exploited by the entrepreneurial developer in research and technology. Earth orbit offers an advantageous situation for communications, navigational data, or for a synoptic or global view of the Earth or its environment. Space also offers several unique physical environments such as:

- Weightlessness or "free-fall" (microgravity; micro-G);
- Hard vacuum with the equivalent of very high pumping rates;
- Exposure to: high kinetic energy atomic oxygen (in Low Earth Orbit), direct solar radiation or the radiation sink of deep space, and other aspects of the space thermal and radiation environment.

These factors are important to consider in gaining insights as to how the space environment can help to obtain new information or permit new or enhanced processes of commercial interest. Also, the precise ambient environment of space is modulated by the carriers or modes of accommodations utilized, operations and even the presence of the instrumentation of interest itself. In addition, the mode of transportation to space, and recovery as needed, can present other and often severe environments plus other requirements. These factors are important to consider in designing the equipment that will be used in space.

For many investigations the most significant feature of space is micro-G. Acceleration disturbances and gravity gradients may have to be accounted for, but sustained periods of "weightlessness" allow the examination or exploitation of physical processes in ways difficult or impossible to achieve on the ground. There are also possibilities for a range of sustained acceleration levels. If you have questions about the environments of specific carriers or modes of transportation or accommodations, use the contacts provided for those systems. If you have questions about the space environment in general, contact us and we will attempt to respond to you.

The first step towards accessing space is a thorough review of the goals and technical objectives of the investigations in order to help establish the rationale for and viability of space related activities. Exploratory steps may be taken in laboratories that simulate or model the physical environments of space. Drop towers and aircraft flying parabolic trajectories provide limited micro-G environments but may allow significant assessments of hardware or operations. Sounding rockets provide access to longer periods of lower micro-G as well as to other space environments to further assess plans or to directly achieve the desired objectives. Similarly, the Shuttle Middeck provides a relatively simple but constrained capability for exploratory,

demonstration or calibration activities, or the capability for obtaining results.

There are a number of paths and options that the commercial researcher should consider in reviewing the means of exploring and explciting the benefits of space related activities. Experience shows best results typically come from a program that proceeds through careful steps and ground testing plus other intermediate capabilities referred to above. The following section reviews the diverse methods of accessing space for commercial research and development.

The NASA Office of Commercial Programs is sure that the exploration of space will result in discoveries of great social and economic benefit. It is our function to facilitate U.S. industry in this process for the enhancement of our Nation, its economy and, thereby, the well being of each citizen. We welcome you aboard and will do our best to assist you.

Garland (Gar) C. Misener, Jr.
Chief, Customer Accommodations Branch
Commercial Development Division
Office of Commercial Programs
NASA Headquarters, Code CCL
Washington, DC 20546
Fax (703) 557-9060 or 557-8186

Chapter 1: Accessing Space

By the year 2000, we expect to see a considerable presences and activity in space with the construction and operation of Space Station Freedom and the development of other orbiting craft of the U.S. and other spacefaring nations. We anticipate entrepreneurs will play an active role in establishing a long-term presence in space, identifying the compelling reasons for space activities in addition to providing capabilities such as orbital payload platforms or man-tended laboratories, and other commercially developed space facilities. Recent U.S. administrations have demonstrated consistent support for the development of the commercial space industry, reviewing and strengthening national space policy to stimulate private sector activity. Toward the middle 1990s, the COMmercial Experiment Transporter (COMET) and other commercially developed facilities will offer more opportunities for space-derived products and services.

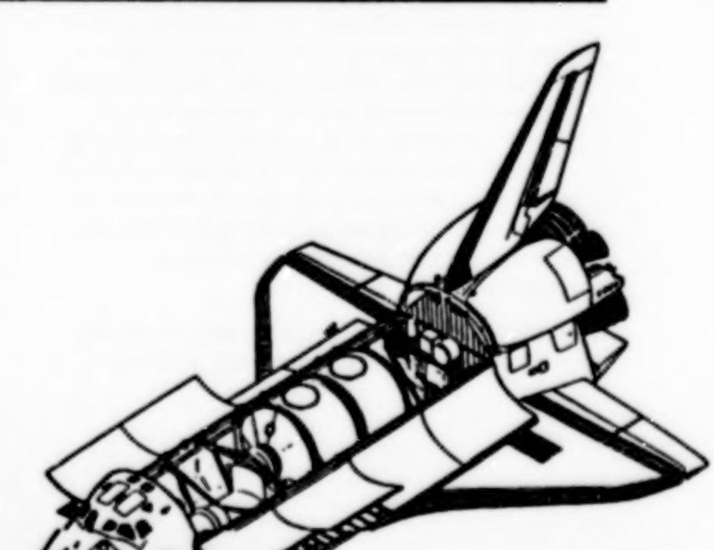
At present, there are several ways for the commercial developer to access space, each of which offers a variety of capabilities to accommodate experimentation. Selection of a vehicle or a facility depends on those capabilities and on the requirements of the project. Accommodation requirements of commercial experiments vary widely. Of prime concern to developers are factors such as experiment control, data handling, electrical power, vibration levels and pointing accuracy, as well as the frequency of flight opportunities.

This chapter offers an overview of these vehicles and facilities and their capabilities for meeting experiment requirements.

Space Shuttle

The most sophisticated vehicle for accessing space and servicing and recovering payloads is the Shuttle (also called the Space Shuttle Program or SSP), where experiments may be conducted for a few hours or as long as several days. Requirements for Earth observation, human intervention, space vacuum and a microgravity environment all are features that characterize the Shuttle as a platform on which to develop research and technology projects.

The Shuttle provides accommodations for a wide variety of experiments in two locations: the cargo bay and the middeck. Advantages and operational restrictions are unique to each area and the choice of carriers and influence experiment design and the means of interfacing experiment hardware.



Space Shuttle (continued)

Middeck and SPACEHAB

The middeck is a confined space located directly below the flight deck and adjacent to the cargo bay. Resources available on the middeck are limited in power, heat-rejection and crew-tending capability. The standard power available is 28 vdc, 115 w. Although space is limited, advantages of experimentation in the middeck include:

- Potential for more frequent flight opportunities
- Reduced payload integration time and cost
- Late access to and early recovery of the experiment package
- Crew interaction with the experiment

The middeck contains mounting space for 42 stowage lockers that normally contain the crew food, clothing and equipment. Unused lockers and/or their mounting spaces are made available for experiment equipment on a mission-by-mission basis. In addition to the locker volumes, the Middeck Accommodations Rack (MAR) is under development to provide additional resources in the middeck (see page 143). At the time of this printing, middeck accommodations were still not available for reimbursable payloads but a pricing policy was in review.

In 1990, NASA's Office of Commercial Programs identified space flight requirements especially in the middeck class that exceed the currently manifested capabilities of the Shuttle, during the period of mid-1992 through 1995.

To help meet these requirements for commercial development flight accommodations and integration services NASA will procure Commercial Middeck Augmentation Modules. NASA has signed a contract with SPACEHAB, Inc., of Washington, DC, for such capabilities, for flights beginning in 1992.

SPACEHAB modules are designed to fly attached in the forward quarter of the Shuttle cargo bay and be accessed by astronauts through a tunnel to the middeck airlock. Each module provides 1,000 cubic feet of additional pressurized volume to the Shuttle and contains accommodations for supporting middeck locker-type payloads and rack-mounted experiments, supplying users with power, data, cooling and crew support resources (see page 148).

Cargo (or Payload) Bay

Larger unpressurized experiments may be accommodated in the cargo bay area, where power and heat-rejection capabilities are available. The cargo bay is 15 feet in diameter and 60 feet in length, occupying the midsection of the Shuttle between the flight deck and crew quarters in the front, and the engine assemblies in the rear. Once in orbit, the cargo bay doors may be opened. In general, cargo bay experiments are fully automated, because crew-tending is not available. Some bay systems do, however, provide a limited data link to the crew cabin for simple control functions.

Carriers

Many carrier systems have been developed for the purpose of conducting science and technology investigations. These carriers involve standard pieces of equipment that serve as a host facility for user instruments and may include one or more mounting structures as well as subsystem interface equipment to tailor such factors as power, communications and environmental controls as required by the particular experiment. Carriers may be pressurized or unpressurized.

Integration time and cost may increase when using large carriers; however, the cargo bay also has provisions for small, self-contained payload carriers that can be integrated rapidly on modest budgets. A number of mounting structures and support systems, known as attached Shuttle payload carriers, make additional space available to researchers at a relatively modest cost; there also are freeflyers that are released in space and later retrieved.

Components and techniques may be tested and qualified for long-duration operations this way, and industrial processes can be evaluated and refined on a small scale before long-range commitments are considered for volume production.

Launch Vehicles

For small experiments, 5-15 minutes of weightlessness can be obtained by using suborbital rockets. Called sounding rockets, these vehicles can launch a small payload up to about 100 miles from Earth; as the payload coasts upward and falls back to Earth, its contents are motionless (weightless) in relation to each other. Although sounding rockets cannot be used for large experiments, the duration of weightlessness produced by the suborbital fall permits commercial developers to explore a wide range of phenomena.

Expendable Launch Vehicles (ELV's) are an alternative to the Shuttle for putting long-term duration experiments in orbit. At present, several launch vehicle companies are developing a new generation of vehicles to accommodate smaller, lighter payloads, such as commercial research experiments, that will be offered at a lower price than larger ELV's. Planning also is underway for a family of small experiment, ELV-based carriers. Demand for these systems is projected to be high, and several developers are designing cost-efficient systems for deploying Low Earth Orbit small payloads.

NASA's Centers for the Commercial Development of Space (CCDS's) are developing a new initiative for launching and recovering commercial payloads on ELV's. The joint project, called COMmercial Experiment Transporter Program (COMET), is scheduled to begin launching in mid-1992. (See page 213 for additional information.)

Opportunities for Commercial Development

Microgravity

Use of ground-based facilities can provide insight into many microgravity processes. For example, very low gravity levels can be achieved in drop towers for short periods of time, allowing scientists to study the interaction of forces in sufficient detail to predict behavior of systems in orbit.

Ground-based facilities present a wide range of options, from R&D laboratories outfitted with sophisticated modeling capabilities, to low-g simulator aircraft, to sounding rockets flying ballistic trajectories. All fit under the rubric of ground-based facilities. The commercial researcher should carefully consider how to exploit these resources since they offer the dual benefits of lower costs and faster integration when compared with orbital operations.

For experiments requiring microgravity conditions, ground-based testing often precedes orbital research. Experiments in these facilities, many of which are located at NASA Field Centers, stimulate ideas for research and serve as the test beds for microgravity research and technology development, such as in the areas of mixing fluids and levitation technology. The Microgravity Materials Science Laboratory (MMSL) at NASA's Lewis Research Center in Ohio is an example of such a facility.

Remote Sensing

Test facilities are available for remote sensing research and technology suited for commercial applications. This field is growing, and equipment such as NASA's large format camera is available for use by the commercial researcher. Remote sensing experiments may be conducted from freeflyers, aboard the Shuttle, on selected aircraft and from specially equipped balloons.

In addition, major achievements have been made in computational research for gathering, integrating, reducing and value-adding data. One of the more advanced programs in this area is based at the Space Remote Sensing Center at the NASA Stennis Space Center in Mississippi, designated as the lead NASA Field Center for remote sensing operations (see pages 29-30).

The Center also manages the Earth Observation Commercial Applications Program (EOCAP), a new approach to leveraging government funds for the purpose of helping the space remote sensing industry establish operational products and services using NASA-developed Earth observations technology. NASA co-funds remote sensing applications research to promote private investments by U.S. industry. Participation includes private sector organizations, educational institutions, other nonprofit organizations and other government agencies. Each participant incorporates an industry partner responsible for commercial implementation of the project. Through this program, businesses are encouraged to invest, over several years, in the development and marketing of high-risk products and services useful to both the private and public sectors. (See also the two Centers for the Commercial Development of Space that are dedicated to remote sensing on pages 38 and 43.)

Opportunities for Commercial Development (continued)

On-Orbit Facilities

On-orbit facilities can provide temporary or long-term exposure to the space environment; as a platform for remote sensing observations, a laboratory for microgravity research, a construction and assembly site or as a docking and resupply site. The Space Station Freedom promises to be one or all of these facilities (depending on the final configuration) at the turn of the century. A strong program is underway to encourage the private sector to develop a consortium relationship with NASA for specific space station-related infrastructure and services.

Before such a station is available however, commercial researchers have several opportunities to investigate the unique qualities of the space environment; its vacuum, radiation, microgravity and global observation perspective. Basic items to consider for experimenting in an on-orbit facility are sufficient volume, power, time on-orbit, data gathering and telecommunications support (as appropriate), sustained microgravity levels (for microgravity research) and pointing capability (as appropriate) and man/robot-attention.

The most immediate opportunity for on-orbit research is on the Shuttle. Missions that fly a 200-mile orbit offer laboratory and observatory time for 5-7 days. An extended duration orbiter (EDO) is under consideration for missions as long as 14 or 28 days. Experiments may be designed to be man-tended or independent; pressurized or unpressurized; and light or heavy, large or small, as required by the research and the accommodations available. Other opportunities for on-orbit research lie in freeflyers, satellites that are launched into orbit by expendable launch vehicles, the Shuttle's expended, refurbished external tank (under development), platforms and Space Station Freedom (under development). These facilities will permit long-term experiment research in space (from several days to several months).

Commercial Payloads on the Shuttle

The first commercial experiment took place on the fourth Shuttle mission in 1982, in the middeck area. Called Electrophoresis Operations in Space (EOS), the project involved a continuous flow electrophoresis system, built to purify biological materials in a microgravity environment. EOS flew on seven missions, 1982-1985. The experiments demonstrated that some 700 times more material can be separated in space than on Earth during the same period, and with better purity levels. The process holds promise for breakthrough drugs and medicines that eventually could save lives and offer new treatments to millions of people suffering from diseases such as diabetes and hemophilia (see page 28).

The first made-in-space product was manufactured on a mission in 1983 and went to market in 1985. Slightly larger than a red blood cell and invisible to the human eye, the product consists of tiny microscopic spheres made of polystyrene, sold in lots of 30 million by the National Institute of Standards and Technology. Microgravity allowed these spheres to grow more uniformly in size and shape than is possible on Earth. Customers use the spheres to help calibrate and focus electron microscopes and to improve microscopic measurements in electronics, medicine, environmental pollution research and other high-technology areas.

Crystal-growth experiments on the Shuttle have demonstrated that the manufacture of crystals in microgravity has tremendous industrial potential. Crystals grown in orbit have fewer imperfections and therefore improved electronic characteristics. Researchers believe such crystals may lead to a new generation of higher-speed microelectronic components for computers, radar and communications systems. During the Spacelab-I mission in 1983, one type of protein crystal grew 1,000 times larger than the same type did on Earth. Such large protein crystals allow bioengineers to study the atomic structures of protein molecules, knowledge essential for designing new drugs. The molecular models derived from such space-grown crystals may well be the foundation for new miracle drugs of the 21st century.

In 1990, NASA's Office of Commercial Programs began a study into the underlying nature of crystal formation, made possible as a result of a payload flown under the 3M Corp.'s first Joint Endeavor Agreement (JEA). After the flight of 3M's Physical Vapor Transport of Organic Solids (PVTOS) payload in 1985, 3M scientists noticed unexpected differences between some of the crystalline thin films grown during the flight and those grown as ground control samples. The implied effects of convection on the resulting film growth may hold clues about crystal formation that can benefit Earth-based crystal growth operations for materials development. Investigators now are interested in studying these samples using fractal analysis which may help determine information about self-ordering mechanisms in the formation of the crystalline microstructure. Several NASA Field Centers, universities and companies are involved in this exciting project.

Opportunities for Commercial Development (continued)

Products and Services

Commercial space businesses are those companies that offer space-related products and services to both government and industry. One of the most well-developed commercial activities is satellite communications, which has flourished since the mid-1960s. Emerging space business activities include products such as:

- Space-processed materials
- Extra-terrestrial materials
- Space-processed finished goods (for space use)

Emerging activities in space services include:

- Advanced transportation systems for launch, inter-orbit and return
- Construction of small- and large-scale structures
- Maintenance and repair of satellites, platforms, stations, transportation vehicles
- Logistics – personnel, food, fuel and supplies
- Laboratory services and manufacturing such as advanced materials
- Communications, audio, video and data position determination systems
- Earth and ocean observation – land, ocean and weather
- Power – solar photovoltaic, solar dynamic, nuclear
- Lodging – room, board and amenities
- Recreation – entertainment, exercise and leisure

Commercial development in the 21st century is likely to fall into two general categories: follow-on phases to current activities in Low Earth Orbit or in Geosynchronous Orbit, such as communications, remote sensing, materials research and materials processing; and new businesses made possible by new infrastructure and routine access to new locations in the Earth-Moon system and, perhaps, on Mars. Examples of new businesses include mining of power resources on the Moon and transportation to and from the Moon. The future holds great promise for private sector initiatives for vehicles, facilities and other products and services. The horizons are limitless.

Other Opportunities

The following are suggested roles and activities, for the commercial developer to consider, that may open up new opportunities:

- Participate as an industrial affiliate in a NASA Center for the Commercial Development of Space. (See page 33.)
- Enter into an agreement with NASA for the development evaluation of specific commercialization projects. Agreements meeting certain objectives of NASA may postpone or reduce transportation costs.
- Participate in an industry council or committee that advises the National Space Council, NASA or another government agency as part of the national space planning process.
- Undertake applications research using results of space-based research or space-produced materials to determine their potential for product use in comparison with their Earth-produced counterparts.
- Participate in multidisciplinary industrial consortia to sponsor space-based research. Initiate and sponsor independent space-based research.
- Explore opportunities in space commerce by tapping the scientific or technical expertise available at NASA, National Institute of Standards and Technology, the National Academy of Sciences and the National Academy of Engineering, and their respective research centers.
- Initiate and develop a project that will provide needed commercial infrastructure to NASA.
- Evaluate the potential applications of satellites, such as communications, remote sensing, and geopositioning and asset tracking.
- Conduct process or product R&D under contract to a government agency in an area that may lead to new private-sector products, services and markets.
- Invest in space enterprise with long-term objectives.

Chapter 2: Accessing the System

NASA's goal is to join hands with industry to develop the potential of the space environment. This partnership is essential for the promise of commercial space to be realized. Any American company, institution or individual may work with NASA to investigate commercial applications of microgravity or remote sensing research, provided the work is consistent with NASA's objective of fostering public benefits through the commercial use of technology. The organization or individual will be required to furnish NASA with sufficient information to verify peaceful purposes and to ensure safety and compliance with applicable laws and regulations.

NASA supports research aimed at commercial applications of space by providing industry access to NASA research facilities and by promoting NASA/industry information exchanges. Toward that end, NASA provides flight time on the Shuttle (as appropriate and available); technical advice, consultation, data, equipment and facilities; and joint research and demonstration programs in which the Agency and the industry each funds its own participation.

NASA also establishes liaisons with industry and academia through its Centers for the Commercial Development of Space (CCDS's), through commercial application working groups and through workshops for potential commercial users of space.

Chapter 2 provides information on many of these activities and arrangements; what they are, how they work and how commercial enterprises work with them to their advantage. This chapter also provides information about using hardware and carriers that either exist or are created/adapted by the researcher; and safety considerations.

NASA Industry Agreements – Space Flight Operations

NASA encourages the commercial community to consider the economic value of space research and development experiments in areas of particular commercial interest. Toward that end, NASA's Office of Commercial Programs established several types of agreements that offer flight time for applied research until the commercial potential of a product has been established. NASA also protects proprietary interests of participating companies within its working agreements as part of its commercial space incentive efforts. These agreements are negotiated on a case-by-case basis and can be tailored to the specific needs of a given project. The terms typically cover such factors as rights to data and patents, process exclusivity and circumstances for recoupment of NASA's investment. These agreements include:

Technical Exchange Agreement (TEA) – appropriate for companies interested in the application of space technology but not ready to commit to a specific space flight experiment or venture. NASA offers technical information and works with companies to develop an idea or experiment.

PRECEDING PAGE BLANK NOT FILMED

NASA Industry Agreements – Space Flight Operations (continued)

Joint Endeavor Agreement (JEA) – applicable for company-sponsored and directed flight experiments. By offering Shuttle flight time and technical advice, NASA can reduce the cost and risk of product development until the commercial viability of key technologies has been established. NASA also offers a Pre-JEA for organizations in the process of defining applied research goals, not yet ready for the JEA.

Space Systems Development Agreement (SSDA) – NASA offers special provisions for launch service, such as deferred payment schedules and exclusivity, to companies developing new systems associated with the development of space hardware infrastructure. Such ventures must have the potential for significant national economic benefits or other substantial benefits.

Launch Services Agreement (LSA) – appropriate for commercial developers who want to purchase Shuttle launch services. Information on pricing and financial planning may be found in the NASA document "STS Reimbursement Guide" (JSC-11802).

NASA Industry Agreements – Ground Operations

Agreements for ground-based experimental research are made on a case-by-case basis, according to equipment, schedule requirements and availability. Where mutual interest can be established, collaborative research efforts involving scientists from industry and NASA are encouraged. Bringing the unique capabilities and expertise of respective organizations to focus on key elements of the research (such as identification of objectives, experiment definition, experiment protocol, sample preparation and sample and data analysis) has proven to be mutually beneficial.

Each party funds its own ground-based research. Terms and conditions, including division of responsibilities, provisions for sharing results and protection of proprietary data are negotiable. A company may request use of testing facilities such as drop tubes and aircraft, independent of collaborative work with NASA, subject to negotiation of mutually acceptable schedules and operating conditions. NASA facilities charge a nominal fee for independent work.

Centers for the Commercial Development of Space (CCDS's)

A company may develop an experiment and handle all integration and scheduling processes directly through NASA or its Field Centers. A company also may choose to work with one of NASA's Centers for the Commercial Development of Space (CCDS's). There are presently more than 175 U.S. firms associated with the 16 CCDS's now operating in locations throughout the nation. Each CCDS tends to focus on a particular field of space-related research that offers potential for commercial in-space production and/or the creation of new products or technologies with high economic value in Earth-based applications. These centers represent disciplines in the following areas:

- Automation and Robotics
- Life Sciences
- Materials Processing in Space
- Remote Sensing
- Space Power
- Space Propulsion
- Space Structures and Materials

Please refer to Chapter 5 for a listing of all CCDS's and their corresponding points of contact.

Hardware Accommodations and Carriers

A commercial researcher may utilize either existing or custom-made equipment for an experiment. In the latter case, he/she must work closely with NASA engineers during the design and construction of this equipment, to provide assurances on its safety, especially for use on aircraft or the Shuttle.

Once the researcher has determined the nature of the experiment, such as orbital (for example, on a Shuttle flight); or ground-based, he/she then must select the type of hardware apparatus and carrier that will be required to accommodate the project. Gaining access to space requires imagination and realistic planning. Keeping experimental designs simple and well-focused may serve to shorten the waiting periods and hold down costs. Selecting the appropriate apparatus, carrier and/or vehicle is essential for obtaining cost-effective, reliable research data.

Existing Hardware

Sometimes suitable existing hardware can be found in the growing inventories of NASA and industry. Certain apparatus and carriers developed by NASA are available through the Field Center that developed them. (Refer to Chapter 4 for a listing of NASA Field Centers.) Equipment developed by private industry is usually available directly through the originating company. As you use this catalogue, you will find that each piece of hardware has a corresponding point of contact for access. Please use these contacts to determine the availability and suitability of such equipment. Equipment may be adaptable for various applications and should be carefully evaluated and modified to suit the requirements of a particular experiment.

Custom-Made Hardware

A major challenge in developing experiment flight hardware is packaging the basic apparatus in a way that meets your objectives and also satisfies equipment and carrier requirements for operations; and meets the design and safety requirements imposed by the testing facility of choice. The instrument must survive the stresses of the launch and flight environment and operate successfully under the given conditions. Consequently, instrument development is a team effort in which the investigator works in close association with engineers and technicians experienced in hardware development. Development and use of flight hardware goes through several phases, which are delineated below.

The Typical Life Cycle of Flight Hardware

- Concept Definition
- Design and Fabrication
- Functional and Qualification Testing
- Delivery, Shipping, Acceptance
- Payload Integration (e.g., on carrier or satellite)
- Cargo Integration (e.g., on Space Shuttle)
- Launch
- Flight Operations
- Re-entry and Landing
- Cargo and Payload Deintegration
- Data Handling and Analysis

Safety

For the benefit of the flight crew and ground personnel who work with and around the experiment equipment, it is essential that investigators comply with certain safety requirements. These requirements cover both flight and ground equipment as well as flight and ground operations. The document "Safety Policy and Requirements for Payloads Using the Space Transport System" (NHB 1700.7) defines safety policy and basic safety requirements. Several other documents have been developed, both generic and carrier-specific, that define approaches for satisfying these requirements (NASA's Office of Commercial Programs can provide information on a case-by-case basis). Ground safety also is a concern. A safety assessment is performed on ground operations to identify and eliminate, or control, hazards associated with any phases of an experiment planned for the Shuttle or any other facility, as required.

Proprietary Aspects

Efforts required to restrict proprietary information may be affected by the mode of accommodations, complexity of interface or the design of the project hardware. This aspect should be carefully thought through. It is important to early and clearly identify to the supportive organizations what is to be treated as proprietary. Such arrangements should be established and agreed to in writing.

Protection of Intellectual Property

The U.S. Patent System is a means by which some measure of exclusivity can be accorded to successful private endeavors in space. As with all entrepreneurial activity, patents for commercial space development can serve as a protection of the earnings for first-to-market inventions and thereby be an important stimulus to industrial progress in space. The greater the ability to obtain and enforce patent rights, the greater the incentive for private enterprise to commit substantial investments in the high-risk undertaking that is inherent in commercial activities in space.

Consistent with the intent to stimulate private initiative and to provide an incentive to space developments, NASA has developed a flexible policy of protecting property rights while encouraging the dissemination of information to promote utilization of space. NASA's objective is to ensure the achievement of technological superiority through arrangements with private U.S. concerns (the reader is referred to *Presidential Memorandum on Government Patent Policy*, 48 Fed. Reg. 22132-33; 1983).

Chapter 3: Accessing Operations

Operations during the experiment itself vary with the nature of the event. For example, ground-based research might be completed in a matter of seconds, with data recorded and prepared for analysis in minutes. By contrast, research on the Shuttle involves more complex systems and therefore requires more planning and interfacing with NASA engineers and officials, data collection during the mission, retrieval of data and experiments after the mission and follow-up on analysis as appropriate.

Key guidelines in developing payloads are:

- The greater the payload size, number of payload interfaces and requirements, the harder it is to manifest.
- The more complex the payload, the more time and effort is required for payload integration.
- The use of proven subsystems and acceptable materials facilitates the integration process.
- Integration and operations are simplified by the design of an experiment that minimizes astronaut training and on-orbit workload.
- The likelihood of mission success is enhanced for astronaut-supported hardware when operational status can be readily determined and alternate or manual modes of operation can be implemented to backup automated operations.
- The commercial developer must meet safety and interface requirements to protect flight and ground crews, carrier systems and facilities and other payloads.

Beyond these basic requirements, developers must determine the level of effort required to meet mission success objectives. Careful and knowledgeable judgments in this area can result in considerable services with minimal risks.

The Shuttle

Pre-Flight

Throughout the life of the project activity the developer should maintain a clear understanding of the objectives, the data necessary to achieve those objectives and how that data (or samples) will be obtained through the entire flow and completion of mission activities.

Planning activities include: verification, crew training, data handling, payload integration plan (PIP), interface control document (ICD), safety reviews, flight development plan and carrier mission development plan.

To ensure that activities perform smoothly on a Shuttle mission, the flight itself is preceded by extensive operations planning and preparation, including identification of payload requirements, timeline, personnel training (if necessary), ground support equipment setup and contingency planning.

The Shuttle (continued)

To facilitate mission planning, investigators should describe the conduct of on-board activity in terms of functional objectives. They also are responsible for providing operating procedures and other reference data such as experiment description, charts and functional schematics for inclusion in the data file.

During the mission, investigators may use their own special processing equipment in addition to those services provided at the control center. Computer compatibility may be an issue to consider in the planning stage and should be discussed with NASA.

Scheduling

To schedule a flight on the Shuttle, the candidate company or Center for the Commercial Development of Space (CCDS) first must submit a Flight Request Form 1637 to NASA's Office of Commercial Programs (OCP). OCP then submits a NASA Form 1628, Request for Flight Assignment, to the NASA Headquarters Transportation Services Division. Generally, the 1628 form is not submitted until OCP has reviewed and approved the payload proposal.

NASA Headquarters sends Form 1628 to Johnson Space Center (JSC), authorizing initiation of the technical integration process. JSC manages the development and operation of the National Space Transportation System (NSTS). If the payload requires Get-Away Special (GAS) or Hitchhiker accommodations, Form 1628 also is sent to Goddard Space Flight Center (GSFC).

Before technical integration begins, a formal agreement (such as a Joint Endeavor Agreement) must be negotiated between the customer and NASA. This agreement covers all business, policy, legal and financial aspects of the launch. Flight agreements exist between NASA and each CCDS.

The CCDS's and individual firms having agreements with NASA-sponsored activities are typically centered around the development and space flight of a particular hardware configuration designed to accomplish some part of an objective, or more than one objective. Such hardware configurations are called "payloads" and such firms sponsoring the requirements for space flight are called "payload sponsors."

For each payload or payload series (two or more flights of a payload with essentially the same configuration and accommodations requirements) a Payload Representative is identified by the payload sponsor to provide the official and primary point of contact for the activity regarding technical information, and to act as the signature authority for agreements and commitments to NASA regarding integration and mission operations. The payload representative is either an employee of the CCDS or the NASA Agreement Partner sponsoring the payload.

OCP's Commercial Development Division provides technical review and support of candidate flight activities, and the assignment of those activities to specific flight opportunities. During the implementation of activities leading to flight, NASA tracks the progress and problems associated with payload and mission implementation in order to determine potential impact on flight assignments and other support provided.

Once Johnson Space Center receives authorization to begin work on a commercial payload, it assigns a Payload Integration Manager (PIM) who remains the primary point of contact for the payload customer throughout the entire technical integration process. The PIM is responsible for ensuring that the customer's requirements are defined and documented properly. The PIM also coordinates engineering and other technical support required at JSC, including payload safety reviews.

Preparatory and operational phases of a Shuttle mission normally require the customer to participate in experiment activities, including payload integration and checkout at Kennedy Space Center (KSC) in Florida. KSC assigns a Launch Site Support Manager (LSSM) to serve as the customer's point of contact at the launch and landing sites, to handle the launch site support plan and payload processing support.

For payloads requiring GAS or Hitchhiker (see pages 154 and 155) experiment carriers, the customer's initial contact is with the Customer Support Manager (CSM) at GSFC. The customer submits a Payload Accommodations and Requirements document for GAS payloads or a Customer Payload Requirements document for Hitchhiker payloads. These are used to develop a Payload Integration Plan and, if required, an Interface Control Document. These papers, together with Safety Data Packages and other documentation, are submitted to JSC.

After all required data is completed and considered with applicable ground rules, constraints and guidelines, payloads with compatible orbital requirements and configurations are manifested together. Flight assignment of the primary and complex secondary payloads occurs 19 months prior to launch and is referred to as the Flight Definition Requirements Directive timeframe. NASA presents results of a detailed cargo engineering analysis in a Cargo Integration Review about a year before launch. Payload customers are encouraged to participate in this review to ensure all requirements have been satisfied. NASA assigns standard payloads at a Flight Planning and Storage Review, seven months before

The Shuttle (continued)

launch. This is the last review in which payloads can be assigned to a Shuttle flight.

For more information about the Shuttle manifesting process, contact Flight Requirements and Manifesting, Commercial Development Division, NASA/Office of Commercial Programs, Washington, DC 20546, (703) 557-5328. Additional information is included in the NASA Publication, NSTS 07700, Volume XIV.

Integration

The primary goal of any experiment process is to assemble it on a carrier in a way that meets safety requirements and provides the desired level of assurance of meeting objectives. Integration is accomplished in two major phases:

Analytical Integration – involves the planning, analysis and preparatory tasks of payload hardware design.

Physical Integration – includes assembly and check-out of the payload apparatus and carrier hardware.

Flight operations planning and preparations are an essential part of the payload integration process. The researcher submits operations requirements to the assigned NASA manager. These requirements are incorporated into the mission, together with the requirements of other experiments and host carrier elements. A small, independent payload, such as in a Get Away Special (GAS) canister, does not require extensive integration tasks.

Mission planning for integrated payload flight operations begins with the preliminary definition and analysis of individual functional and resource requirements and culminates in the production of a nominal mission timeline, crew activity plan and other flight definition data concerning targets, launch windows, attitudes, etc. A detailed flight operations analysis resolves conflicts and allocates operating times and resources. Once a Payload Integration Plan is agreed upon by all parties, flight preparations proceed. The researcher also may be required to develop flight procedures, assist with crew training, and participate in simulations and in real-time operations.

Post-Flight

When the Shuttle has landed, the researcher has to retrieve and analyze the data or other products generated during the flight.

Normal removal of experiment flight equipment begins about a week after landing. However, special access to remove time-critical data and products or items is possible within days or hours, and should be discussed well in advance with the assigned NASA manager. Experiment hardware is returned to the developer or the NASA inventory, as appropriate, after the deintegration of the payload.

Ground-Based Facilities, Aircraft and Expendable Launch Vehicles

Operations

Operations procedures are as important to tests in laboratories on drop towers, experimental aircraft and expendable launch vehicles as they are on the Shuttle. However, as stated earlier, these operations may be considerably simplified, depending on the design of the experiment and the vehicle or facility being employed. As with all research, the more planning and analysis that is performed prior to the actual testing, the more control and data analysis is possible. Discuss with the facility personnel all variables and concerns of the experiment during the planning process. Such caution will help to avoid last-minute surprises that may force a delay or problem in the testing process.

Scheduling Facilities

Use of facilities such as aircraft and drop tubes may be requested directly through NASA Field Centers (see points of contact in Chapters 4 and 23). Low-gravity flights of KC-135, F-104 and Learjet simulator aircraft are achieved by flying a prescribed parabolic trajectory and are made frequently. Lead-time for scheduling experiments on such flights typically varies from one to six months, depending on the nature of the experiment and aircraft availability. Other facilities, including those at field centers and laboratories, may be similarly requested for use. As stated earlier, negotiations can be made with NASA for the use and cost of facilities and, where sufficient mutual interest exists, collaborative research may be arranged.

While projects that fly on the Shuttle require considerably more planning and documentation than other projects, it is advisable to follow NASA project management practices in conducting any type of experiment.

Ground-Based Facilities, Aircraft and Expendable Launch Vehicles (continued)

Scheduling Facilities (continued)

Typical experiment project documentation includes such items as:

- Payload Integration Plan
- Interface and Control Document
- Ground and Flight Safety Plans
- Crew Timeline Plan

More specific information about the scheduling process for aircraft, drop tubes, sounding rockets or other facilities is available from the Commercial Development Division of the Office of Commercial Programs upon request. It is OCP's mandate to reach out to the commercial community, to offer information, assistance or liaison staff as needed. Obtain as much information as possible about your particular research needs, taking advantage of the experience, advice and materials available from NASA and industry.

Contact: Commercial Development Division
Office of Commercial Programs
NASA Headquarters,
Washington, DC 20546
(703) 557-4626

Section Two: Ground-Based Testing

Performing an experiment in space presents many challenges to the designer in assuring that the hardware – and the experiment – survives the mission. Many facilities have been created to support this endeavor. These facilities support space-related activities, from developing and testing a new material, to research facilities, such as the Microgravity Materials Science Laboratory at NASA/Lewis Research Center. This laboratory has the capability to simulate microgravity conditions. Several experimental research facilities have drop tubes, drop towers and aircraft which also can simulate a microgravity environment for a limited period of time.

Facilities devoted to sensor development, data processing and data distribution play an important role in the Remote Sensing Programs. Remotely sensed information is gathered by space-based and airborne vehicles and instruments. Remote sensing systems include a wide variety of highly sophisticated hardware, software and other subsystems.

Facilities at the NASA Field Centers are grouped into several major classifications. These include basic research, manufacturing processes, commercial applications of remote sensing, materials testing and performance testing, which includes environmental facilities such as vacuum chambers, centrifuges and vibration tubes. In general, the Centers for the Commercial Development of Space (CCDS's), industry and university facilities follow the same grouping, although the commercial facilities also include clean rooms and other space-related fabrication areas.

The commercial developer must test all experiment equipment and design before attempting to place any research project in space. Such testing allows for evaluation of the integrity of the experiment, survivability of the equipment and quality control of all functioning processes and devices to ensure successful results. NASA can advise which approach will best meet the requirements.

Airborne flight facilities provide the opportunity for such testing and evaluation. They also permit research programs of various disciplines, which may not be applicable for space flight. These facilities include sounding rockets, aircraft, helicopters and balloons.

Chapter 4: Facilities at NASA Field Centers

NASA has assembled a large inventory of developmental, research, environmental and test equipment for space-related hardware. Equipment names and/or functions are listed here; further information regarding capacities and other pertinent specifications may be obtained by contacting the NASA Field Center Commercialization Officers listed in Chapter 23. Additional information about NASA facilities may be found in the publication "NASA Facilities Database User's Manual" or by contacting the Office of Commercial Programs, Commercial Development Division, at (703) 557-4626.

Ames Research Center

Located in Mountain View, CA, Ames Research Center covers some 420 acres on land adjacent to the Moffet Field Naval Air Station. Ames specializes in scientific research, exploration and applications aimed toward creating new technology. It houses extensive research facilities, many of them unique, including the world's largest wind tunnel.

The Center's major programs are concentrated in computer science and applications, computational and experimental aerodynamics, flight simulation, flight research, hypersonic aircraft, rotorcraft and powered-lift technology, aeronautical and space human factors, life sciences, space sciences, solar system exploration, airborne science and applications and infrared astronomy.

Life Sciences/Biotechnology Facilities

- 20 G/Human Centrifuge
- Altitude Chambers
- Animal Centrifuges
- Flight Simulation Facilities
- Human Performance Research Laboratory
- Isotope Biogeochemistry Laboratory
- Life Sciences Flight Experiments Facility
- Plant Growth Chambers
- Proximity Operations Simulator
- Psychophysiology Laboratory
- Structural Systems and Bone Mineralization Laboratory

Performance Testing Facilities

- Centrifuge
- Impact Shock and Dynamic Balance Facilities
- Magnetic Test Facility
- Temperature Altitude and Humidity Chamber
- Tensile Test Machine
- Vibration Exciter

Materials Testing Facilities

- Ultrastructure Research Laboratory (Scanning Electron Microscopes)

Contact: Elizabeth Inadomi
Manager of Commercial Programs
NASA/Ames Research Center, MS 223-3
Moffett Field, CA 94035-1000
(415) 694-6472, Fax (415) 694-4004

Ames Aircraft Data Facility

Image Processing Laboratory – The Ames Aircraft Data Facility has an Image Processing Laboratory, concentrating on photographic and electronic data processing, used in conjunction with remote sensing programs. Further information on these capabilities may be obtained from NASA/ARC, Aircraft Data Facility, (415) 604-6252.

NASA High Altitude and Medium Altitude Photography Archive – The Aircraft Data Facility also hosts the NASA High Altitude and Medium Altitude Missions Photography Archive, which contains thorough coverage of the western and eastern states, including Alaska and Hawaii, with significant coverage of the South and Midwest. Urban, suburban, agricultural and even the most remote mountain regions are represented.

Archive photographs present wide ground coverage and precise definition of ground objects: each 9x9 inch or 9x18 inch frame depicts 32 to 256 square nautical miles of the Earth's surface, with a nominal resolution of 5 to 15 feet. Archive film consists of three types: natural color, black and white and color infrared. Color infrared film is the most widely used

PRECEDING PAGE BLANK NOT FILMED

Ames Research Center (continued)

because it produces photographs that reveal information from a portion of the spectrum normally not seen by the eye. Color infrared photographs are particularly useful for noting the differences within land cover types (water, soil and vegetation).

Image Selection System – The Aircraft Data Facility maintains a computerized database called the Image Selection System (ISS) for locating specific frames of photography of designated areas. Facility staff use the ISS to specify the area, year, film format, film type and scale of photography of potential interest to archive users. By quickly viewing microfilm versions of frames listed by the ISS, users can verify their selections before accessing rolls of film.

Viewing equipment is provided so that visitors can study specific films of interest. This equipment includes light tables, stereo viewers, a transfer scope and a complete set of U.S. Geological Survey topographical maps of the United States, at a scale of 1:250,000. With the transfer scope, users can overlay a photograph with a map or second photograph and then, while viewing them simultaneously, transfer photo-interpretive data to the map or photo overlay. Archive photography is for on-site use only. However, copies of any frame can be obtained by contacting the Earth Remote Observation Sensing Data Center in Sioux Falls, SD, 57198, (605) 594-6151 (see also EOSAT, Chapter 9).

Contact: Gary A. Shelton
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Ames Dryden Flight Research Facility

The Ames Dryden Flight Research Facility is located at Edwards Air Force Base, CA, in the Mojave Desert. Ground-based facilities include a high-temperature loads calibration laboratory that allows testing of complete aircraft and structural components under the combined effects of loads and heat; a highly developed aircraft flight instrumentation capability; a flight systems laboratory with a diversified capability for avionics system fabrication, development and operations; a flow visualization facility that allows basic flow mechanics to be seen on models or small components; a data analysis facility for processing of flight research data; a remotely piloted research vehicles facility; and a test range with communications and data transmission capability.

Goddard Space Flight Center

Goddard Space Flight Center, at Greenbelt, MD, is a national facility that has the expertise to conceive missions, to design, develop, fabricate and test spacecraft, and to operate flight projects and analyze data returned from them. Engineering laboratories are focused on advanced space technologies for applications to new spacecraft and payload systems. In addition to disciplines such as ultra violet and infrared astronomy, solar physics, high energy astrophysics, planetology, climatology and Earth sciences, scientists and engineers also are developing infrastructure, such as automation and robotics, for space station and exploration applications.

Goddard catalogues and archives its scientific data from experiments at the National Space Science Data Center in the form of magnetic tapes, microfilm and photographic prints. Theoretical research is conducted at the Goddard Institute for Space Studies, in New York City.

Performance Testing Facilities

- Acoustic Test Facility
- Ainsworth Vacuum Balance Facility
- Battery Test Facility
- High Capacity Centrifuge Facility
- High Speech Centrifuge Facility
- High Voltage Test Facility
- Large Area Pulsed Solar Simulator
- Magnetic Field Component Test Facility
- Magnetic Test Facility – 45 ft
- Optical Instrument Assembly and Test Facility
- Radiation Test Facility
- Shielded Room EMI Test Facilities
- Space Simulation Test Facility
- Spacecraft Magnetic Test Facility
- Vacuum Chamber (8 ft x 8 ft)
- Vibration Test Facility

Materials Testing Facilities

- Fatigue, Fracture Mechanics and Mechanical Testing Laboratory
- Metallography Laboratory

Goddard Space Flight Center (continued)

Materials Testing Facilities (continued)

- Organics Analysis Laboratory
- Outgassing Test Facility
- Parts Analysis Laboratory
- Scanning Electron Microscope Laboratory
- X-ray Diffraction and Scanning Auger Microscope Spectroscopy Laboratory

Manufacturing Process Facilities

- Gold Plating Facility
- Optical Thin Film Deposition Facility
- Paint Formulation and Applications Laboratory

Contact: Donald S. Friedman
Chief, Office of Commercial Programs
Goddard Space Flight Center
Mail Stop 702, Building 11, Room C1
Greenbelt Road
Greenbelt, MD 20771
(301) 286-6242, Fax (301) 286-4653

National Space Science Data Center (NSSDC)

NSSDC was established by NASA to serve the Space and Earth Science research communities. It is an active repository for data obtained from space science investigations. Since its establishment, NSSDC has been responsible for the active collection, organization, storage, announcement, retrieval, dissemination and exchange of data received from satellite experiments.

Information on sounding rocket investigations also has been collected. In addition, NSSDC has collected correlative data from ground-based observatories and stations for NASA investigators, and for on-site use at NSSDC, in the analysis and evaluation of space science experiment results.

NSSDC actively collects, organizes, stores, announces, disseminates, exchanges and refers to a large variety of scientific data obtained from spacecraft and ground-based observations. Disciplines represented include:

- Astronomy
- Astrophysics
- Atmospheric sciences
- Ionospheric physics
- Land sciences
- Magnetospheric physics
- Ocean sciences
- Planetary sciences
- Solar-terrestrial physics

A user may request data and documents in any of the following ways:

- Letter request
- Document request form
- Telephone request
- On-site request
- Telex
- Networks

Contact: NSSDC
NASA/Goddard Space Flight Center
Code 930
Greenbelt, MD 20771
(301) 286-6695, Fax (301) 286-4952

Jet Propulsion Laboratory

The Jet Propulsion Laboratory in Pasadena, CA, is a government-owned facility operated by the California Institute of Technology. JPL operates the worldwide Deep Space Communications Complex, a station of the worldwide Deep Space Network, and maintains a substantial technology program to support present and future NASA flight projects and to increase laboratory capabilities.

JPL is engaged in activities associated with deep space automated scientific missions, such as engineering subsystems and instrument development, and data reduction and analysis. It also designs and tests flight systems, including complete spacecraft, and provides technical direction to contractors.

Performance Testing Facilities

- Acoustic and Measurement Laboratory
- Ion Source Laboratory
- Space Simulator – 10 ft
- Space Simulator – 25 ft
- Thermal Vacuum Chamber (7 ft x 14 ft)

Materials Testing Facilities

- Magnetics Test Laboratory
- Materials Characterization Laboratory
- Materials Research Laboratory

Research Facilities-Propellants

- Chemical Synthesis Laboratory

Contact: William T. Callaghan
Manager, Technology Commercialization
NASA/Jet Propulsion Laboratory
M/X 79-21
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-0865, Fax (818) 354-7282

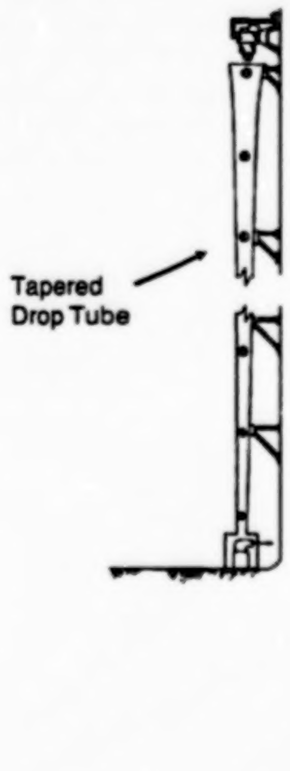
13.1-Meter Force-Free Drop Tube

The 13.1-meter force-free drop tube is used in fluid surface configuration research. The facility provides investigators with a microgravity environment lasting up to 1.6 seconds, but unlike other drop tubes, this one is free of aerodynamic drag. Gravity and air drag distort the subtle characteristics of fluids; under microgravity conditions, these features may be more readily observed.

Operational Characteristics

Sample size:	Up to 5 cm diameter
Tube size:	13.1 m L x 12.7 cm diameter
View port diameter:	5.0 cm
Temperature:	ambient room
Microgravity duration:	Up to 1.6 seconds
Acceleration level:	1 milli-g or greater

Contact: NASA/Jet Propulsion Laboratory,
Applied Sciences and Microgravity
Experiments Section
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-7125



13.2-Meter Cryogenic Drop Tube

The 13.2-meter cryogenic drop tube provides a very low-temperature, controlled gas environment for the development of spherical shell technology, fusion target investigations, and the processing of metallic glass and metal alloys.

The sample to be processed in the 13.2-meter cryogenic drop tube is melted in a crucible that also injects the molten material with gas bubbles. The sample begins its 1.7-second free fall through the three temperature zones of the tube as a hollow stream, a cylinder of molten material surrounding a gaseous center. In the first zone of the tube, the sample is cooled to slightly below its melting/liquidous temperature, allowing the stream to pinch off into symmetrical droplets that surround gas bubbles. Each droplet then enters the cryogenic zone where the molten material cools around the gas bubble, forming a spherical shell. This second zone is chilled by a 10.66-meter liquid nitrogen (LN_2) cooling jacket that chills to LN_2 temperature in approximately 2 hours.

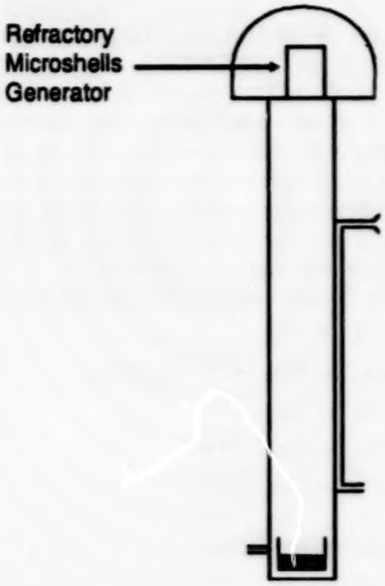
Operational Characteristics

Size of shells produced:	100 microns to 3 mm
Sample materials:	Aluminum, plastics, metal alloys, special glasses
Crucible size:	500 to 1,000 ml
Tube size:	13.2 m L x 12.7 cm diameter
Internal gas pressure range:	1×10^{-5} torr to 1 atm
Microgravity duration:	1.7 seconds

Temperature

Crucible:	Up to 2,000° C
First zone:	Approximately 450° C
Second zone:	Down to -195° C
Third zone:	Ambient room temperature

Contact: NASA/Jet Propulsion Laboratory
Applied Sciences and Microgravity
Experiments Section
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-7125



Johnson Space Center

Johnson Space Center is located on 1,620 acres in Clear Lake, TX, about 20 miles from Houston. JSC is the main center for design, development and testing of spacecraft and associated systems for manned flight; selection and training of astronauts; planning and conducting manned missions; and extensive participation in the medical, engineering and scientific experiments carried aboard space flights.

In addition to its primary responsibilities of program management for the Shuttle and development of the Space Station, JSC also has sixteen facilities dedicated to space and life sciences, including planetary and Earth sciences, robotics, artificial intelligence and lunar samples. Engineering facilities include vacuum chambers, an anechoic chamber, antenna range, avionics testing and various structural and environmental test areas.

Life Sciences/Biotechnology Facilities

- Biochemistry Research Laboratory
- Bioprocessing/Cell Biology Research Laboratory
- Crew Systems Laboratory Complex
- Endocrinology Research Laboratory
- Environmental Physiology Laboratory
- Health Physics Laboratory
- Life Sciences Experiments Development, Assembly and Verification Facility

Materials Testing Facilities

- Electron Microprobes
- Electron Microscopy and Photographic Equipment
- Gas Analysis Equipment
- Gas Toxilogical Analysis Equipment
- Thermal Analysis Equipment

Research Facilities – Space Plasma

Space Plasma Simulation Laboratory

Johnson Space Center (continued)

Manufacturing Process Facilities

- Laser/Electro-Optical Laboratory
- Performance Testing Facilities
- Crew Systems Laboratory Complex (6 chambers)
- Space Environmental Effects Laboratory (14 chambers)

Contact: Mark Nolan
Manager of Commercial Programs, Code IC
NASA/Johnson Space Center, EA-111
Houston, TX 77058
(713) 283-5320, Fax (713) 283-5305

Kennedy Space Center

Kennedy Space Center includes 84,031 acres on the East Coast of Florida. The Center is responsible for the assembly, checkout and launch of Space Shuttle vehicles and their payloads, landing operations and the turn-around of Shuttles between missions, as well as preparation and launch of expendable launch vehicles. It supports spacecraft requirements of other NASA Centers, commercial organizations and U.S. government agencies not affiliated with the Department of Defense by providing operational and administrative support.

Life Sciences/Biotechnology Facilities

- Animal Holding Facility
- Biomass Production Chamber
- Biomedical Stress Laboratory

Materials Testing Facilities

- Coating Facility
- Electronic Laboratory
- Failure Analysis Laboratory
- Lubricants Laboratory
- Material Testing Laboratory
- Metallurgical Laboratory
- Metrology Laboratory
- Microchemical Analysis Laboratory

Other Research Facilities

- Artificial Intelligence Laboratory
- Fiber Optics Laboratory
- Gas Chromatography Laboratory
- Robotics Applications Development Laboratory

Performance Testing Facilities

- Liquid Oxygen Test Facility
- Temperature Humidity Chamber

Manufacturing Process Facilities

- Plastic and Elastomers Facility

Contact: Mr. Robert (Bob) Butterfield
Manager, Technology Integration
Code PT-PMO-A
NASA/Kennedy Space Center, FL 32899
(407) 867-3017, Fax (407) 867-2217

Langley Research Center

Located in Hampton, VA, the Langley Research Center occupies nearly 790 acres of government-owned land and shares aircraft runways, utilities and some facilities with neighboring Langley Air Force Base. An additional 3,200-acre marshland is under permit to NASA and is used as a drop zone for model aircraft tests.

Langley's primary mission is basic research in aeronautics and space technology. Major research fields include aerodynamics, materials, structures, controls, information systems, acoustics, aeroelasticity and atmospheric sciences. About 60 percent of the work at Langley is in aeronautical research, with the remainder focused on space research. Space researchers conduct studies in atmospheric and Earth sciences, identify and develop technology for advanced space transportation systems, conduct research in laser energy conversion techniques for space applications and provide the focal point for design studies for large space systems technology and Space Station Freedom activities.

Langley Research Center (continued)

Performance Testing Facilities

- Mast Test Facility
- Potentially Hazardous Test Areas
- Thermal Chambers
- Thermal Vacuum Chamber (8 ft x 15 ft)
- Thermal Vacuum Chamber (55 ft)
- Vacuum Bell Jar Systems
- Vacuum Braxing
- Vacuum Chamber (5 ft x 5 ft)
- Vacuum Sphere – 60 ft
- Vibration Facility – 17,000 lb
- Vibration Facility – 37,000 lb

Materials Testing Facilities

- 5 Megawatt Arc Tunnel
- 20 Megawatt Arc Tunnel
- Carbon/Carbon Fiber Laboratory
- Combustion Tunnel
- LOX Combustion Tunnel

Microgravity Research Facilities

- Flow/Solidification Front Apparatus

Polymer and Fiber Optics Research Facilities

- Gas Permeable Membrane Laboratory
- Gas Phase Chemistry (Mass Spectrometer)
- Sensible Fibers

Contact: Fred Allamby
Commercial Project Manager
NASA/Langley Research Center, MS 356
Hampton, VA 23665-5225
(804) 864-3788, Fax (804) 864-3769

Lewis Research Center

Lewis Research Center occupies 360 acres of land adjacent to the Cleveland Hopkins International Airport, near Cleveland, OH. Lewis is NASA's lead center for research, technology and development in aircraft propulsion, space propulsion, space power and satellite communications. Lewis is responsible for developing the space power system that will provide electrical power necessary to accommodate the life support systems and research experiments planned for Space Station Freedom. The Center also will support the Station in other areas such as auxiliary propulsion systems and communications.

Lewis is the home of the Microgravity Materials Science Laboratory, a facility uniquely designed to qualify potential space experiments. Other facilities include a zero-gravity drop tower, wind tunnels, space tanks, chemical rocket thrust stands and chambers for testing jet engine efficiency and noise.

Microgravity Research Facilities

- Microgravity Materials Science Laboratory
- 145-meter (5.2 second) Drop Tower
- 30-meter (2.2 second) Drop Tower
- Learjet
- General Purpose Crystal Furnaces
- Electromagnetic Levitation Furnace with Drop Tube
- Transparent Crystal Growing Furnaces

Other Research Facilities

- Energy Conversion Laboratory
- Space Power Research Laboratory
- Materials and Structures Laboratory
- Materials Processing Laboratory
- Basic Materials Laboratory
- Thermal Vacuum Test Facilities (up to 31 m diameter x 37 m high)
- Rocket Engine Test Facility
- Power Systems Facility
- Surface Sciences Laboratories
- Materials Characterization Laboratories
- Polymer Science Laboratories
- Glass Laboratory

Contact: Harvey Schwartz
Manager, Office of Industrial Programs
NASA/Lewis Research Center, MS 3-17
Cleveland, OH 44135
(216) 433-2921, Fax (216) 433-5266

Lewis Research Center (continued)

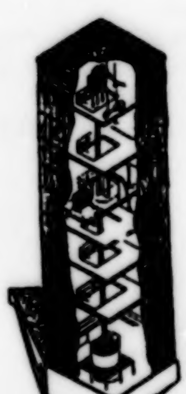
30-Meter Drop Tower

The 30-meter drop tower (also known as the 2.2 Second Drop Tower) at the NASA Lewis Research Center plays a key role in the discipline of Microgravity Science and Applications. This facility allows investigators to test experimental packages in a microgravity environment for a period of 2.2 seconds. It is used extensively by NASA research scientists as well as university investigators. The current focus of the programs utilizing the facility are in the areas of combustion science and fluid physics. The role of the drop tower in these areas includes the execution of ground-based science programs, the performance of tests to define space experiment science requirements and conceptual designs, and to perform tests for space experiment technology development and verification. The drop tower is an ideal research facility as it is operated at a relatively low cost. Engineers participate directly in experiment build-up and testing, and several drop tests (8 to 12) can be performed in one day.

Operational Characteristics

Sample rectangle drop rig:	41 cm W x 96 cm L x 84 cm H
Experiment hardware weight:	up to 125 kg
Drop height:	27 meters
Drag shield dimensions:	51 cm W x 102 cm L x 137 cm H
Microgravity duration:	2.2 second (free fall)
Gravitational acceleration:	Less than 10^{-5} g
Deceleration rate:	40 to 70 g for less than 20 millisec

Contact: Jack Lekan
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-3259



30-Meter Drop Tower

145-Meter Zero-Gravity Research Facility

The 145-meter Zero-Gravity Research Facility, with a vacuum drop chamber, has been developed in support of microgravity research and development programs that investigate various physical sciences, materials, fluid physics, and combustion and processing systems. Large experimental packages can be operated and observed for periods of 5 seconds of microgravity.

Operational Characteristics

Sample cylindrical vehicle

Size:	1.5 m x 1.0 m diameter
Cold gas thrust system:	0.003 to 0.015 g
Experiment payload weight:	Up to 453.6 kg
Total system weight:	1.135 kg

Sample Rectangular Vehicle

Dimensions:	1.5 m L x 0.5 m W x 1.5 m H
Test Specimen Envelope:	1.5 m L x 0.40 m W x 0.45 m H
Cold gas thrust system:	0.003 to 0.037 g (positive) 0.013 to 0.070 g (negative)
Experiment payload weight:	Up to 69 kg
Total vehicle weight:	340 kg

Vacuum Test Chamber

Drop height:	132 m
Ultimate vacuum:	10^{-2} torr (in 1 hour)
Aerodynamic drag:	Less than 10^{-6} g
Microgravity Duration:	5.18 seconds

Deceleration Rate

Mean:	35 g for 150 millisec
Maximum range:	60 g for 20 millisec

Contact: NASA/Lewis Research Center
Space Propulsion Technology Division
Cleveland OH 44135
(216) 433-5485

Lewis Research Center (continued)

Microgravity Materials Science Laboratory

The Microgravity Materials Science Laboratory is a nationally available laboratory open to scientists and engineers from U.S. industry, universities and governmental agencies. It is equipped with experimental hardware with three objectives: it emulates some aspect of a reduced gravity environment (e.g., containerless processing); provides an improved 1-g database for experiments and processes which are candidates for space research; and functionally duplicates hardware which is used on the Shuttle or is being developed for Shuttle/Space Station missions.

The MMSL is designed to give promising experimenters easy access to its specialized facilities. The researcher can evaluate the results of a simple "proof of concept" experiment before a formal program at his/her home laboratory is begun, permitting the researcher's sponsoring organization to do exploratory research without committing large sums of money. Use of MMSL facilities is free of charge for non-proprietary research; cost-of-usage contracts can be negotiated for proprietary work.

The MMSL currently provides experimental capabilities to support research in crystal growth, metals and alloys, ceramics, glasses and polymers.

Available experimental equipment includes an electromagnetic levitator and instrumented, one-second drop tube; a transparent crystal growth furnace; a magnetically damped, high temperature directional solidification furnace; a bulk undercooling furnace; a transparent dendrite growth apparatus; and an acoustic levitator. Additional equipment may be purchased or built to meet user needs.

The MMSL is the home of two of NASA's Advanced Technology Development (ATD) projects. One of these projects centers on furnaces with improved efficiencies; these furnaces will be useful for both ground-based and flight research. The other ATD project is examining the possibility of placing a laser light-scattering instrument on the Shuttle or Space Station. This sensitive characterization tool measures particles in solution which range in size between 30 angstroms and 3 microns and can be used to watch evolving polymerization or agglomeration.

Contact: MaryJo Meyer
NASA/Lewis Research Center
MS 105-1, MMSL
Cleveland, OH 44135
(216) 433-8165

Marshall Space Flight Center

Marshall Space Flight Center is located on 1,800 acres inside the U.S. Army's Redstone Arsenal in Huntsville, AL. Marshall also manages the Michoud Assembly Facility in New Orleans, LA, where the Shuttle external tanks are manufactured, and the Slidell Computer Complex in Slidell, LA, which provides computer services support to Michoud.

Primarily a launch vehicle development center, Marshall is a multi-project management, scientific and engineering establishment, with much emphasis on projects involving scientific investigation and application of space technology to the solution of problems on Earth. The Center plays a key role in the development of Shuttle payloads, such as Spacelab, a reusable, modular scientific research facility carried in the Shuttle's cargo bay.

Marshall also is involved in the investigation of materials processing in space, including research to understand and improve Earth-based processes and the formulation of space-unique materials. New techniques were demonstrated in past Spacelab missions, such as formation alloys from normally immiscible products and the growth of near-perfect large crystals, impossible to grow on Earth.

Microgravity Research Facilities

- Advanced Space Furnace Technology Laboratory
- Crystal Growth and Characterization Laboratory
- Glass Sciences Laboratory
- Holography and Optical Analysis Laboratory
- Holography Ground System Laboratory
- Low-g Fluid Dynamics Laboratory
- Solidification Processes Laboratory
- Solidification Research Laboratory
- Solution Crystal Growth Laboratory

Manufacturing Process Facilities

- Adhesive Bonding and Composites Development Facility
- Adhesive Technology Laboratory
- Ceramics and Coatings Development and Evaluation Laboratory
- Composite Materials, Adhesives, and Cryogenic Insulation Development and Evaluation Laboratory
- Glass Sciences Laboratory
- Optical Fabrication, Coating and Testing Laboratory

Manufacturing Process Facilities (continued)

- Optical Material and Coating Laboratory
- Optical/Electro-Optical Systems Laboratory
- Polymer Development and Evaluation Laboratory
- Rubber and Plastics Technology Facility
- Superconductivity Thin Film Laboratory
- Vacuum Plasma Spray Development Facility

Life Sciences/Biotechnology Facilities

- Electrophoresis Laboratory
- Phase Partitioning Laboratory
- Space Chemistry Laboratory (Monodisperse Latex Reactor)

Materials Testing Facilities

- Chemistry Diagnostic Laboratory
- General Purpose Rocket Furnace Test Facility
- Polymer Development and Evaluation Laboratory
- Scanning Electron Microscope Facility
- Tensile Test Facility
- Vacuum Physics Laboratory
- Vacuum UV Laboratory

Performance Testing Facilities

- Acoustic Test Laboratory
- Environmental Test Facility
- Magnetospheric Laboratory
- Modal Test Laboratory
- Nondestructive Evaluation Facility
- Solar Array Laboratory
- Thermal Vacuum and Thermal Chambers
- Vacuum Chamber (Senspot I)
- Vibration Test Laboratory

Contact: Kenneth Taylor
Chief, Commercial Materials Processing in Space
NASA/Marshall Space Flight Center
MS PS05
Marshall Space Flight Center, AL 35812
(205) 544-0640, Fax (205) 544-5861

100-Meter Drop Tower

The 100-meter drop tower simulates in-flight microgravity conditions for up to 4.2 seconds for containerless processing experiments, immiscible fluids and materials research, pre-flight hardware design test and flight experiment simulation.

The 100-meter drop tower is designed to accommodate large experiment packages, which are provided by the investigator and contain all instrumentation required for sample melting and internal data collection. These packages are housed in a shield to isolate the experiment from aerodynamic drag during free fall.

Operational Characteristics

Sample size:	0.9 m L x 0.9 m W x 0.9 m H
Sample weight:	180 kg maximum
Sample capacity:	0.73 m^3 maximum
Drop tower	
Total drop height:	101.7 m
Free-fall height:	89.5 m
Drag shield	
Size:	7.4 m L x 2.2 m diameter
Test area:	1.8 m x 2.4 m
Weight:	1,642 kg
Drag shield free-fall time:	4.275 seconds
Drag shield deceleration:	25 g
Auxiliary thrust:	34 kg
Low-gravity range:	1×10^{-5} to 4×10^{-2} g

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA 81
Marshall Space Flight Center, AL 35812
(205) 544-0196

100-Meter Drop Tower

Marshall Space Flight Center (continued)

100-Meter Drop Tube

The 100-meter drop tube simulates in-flight microgravity conditions for up to 4.6 seconds and is used extensively for ground-based microgravity convection research in which extremely small samples are studied. The facility can provide deep undercooling for containerless processing experiments that require materials to remain in a liquid phase when cooled below the normal solidification temperature.

The melting apparatus is housed in a stainless-steel bell jar located directly above a stainless-steel drop tube. After the sample melts, it drops freely through the tube; the melting device does not fall with the sample. The drop tube can be evacuated to a pressure of 10^{-6} torr and accelerations as low as 10^{-6} g are possible for as long as 4.6 seconds.

Operational Characteristics

Sample size:	Up to 5 mm diameter
Sample mass:	Up to 300 mg
Sample shape:	Symmetrical with good aspect ratio
Tube diameter:	25.4 cm
Tube length:	104.0 m

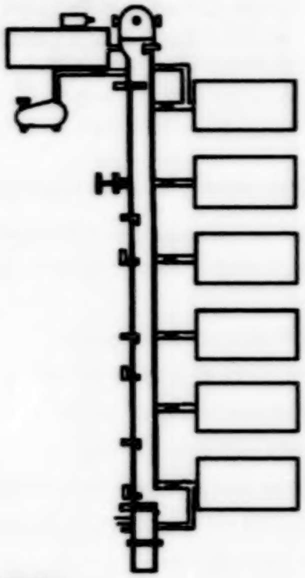
Electron bombardment furnace

Temperature range:	1,600° to 3,500° C
Pressure:	Vacuum environment
Sample shape:	Wire, rod or disc

Electromagnetic levitator furnace

Temperature range:	500° to 3,000° C
Pressure:	Vacuum and low-pressure gaseous environments
Sample weight:	Up to 0.25 g

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



100-Meter Drop Tube

Stennis Space Center

Stennis Space Center is a 13,480 acre complex near Bay St. Louis, MS, that includes industrial, laboratory and specialized engineering facilities to support the testing of large rocket propulsion systems. The main mission of SSC is support of the Shuttle main engine and main orbiter propulsion system testing.

Stennis also has evolved into a Center of Excellence in the area of remote sensing and is involved in Earth sciences programs of national and international significance. The Earth Resources Laboratory develops and manages a balanced research and development program in Earth sciences, remote sensing technique and applications, and sensor and data systems development and operations.

Designated as the lead NASA Center for commercial applications of remote sensing, Stennis has two labs, the Sensor Engineering and Development Lab and the Data Analysis Lab, that assist commercial researchers in participating in the remote sensing arena. SSC features a Visiting Investigator Program (VIP), designed to encourage industry to utilize the Center's facilities. The Earth Observations Commercialization Applications Program (EOCAP) is managed here as well. (continued)

Stennis Space Center (continued)

Remote Sensing Research Facilities

- Sensor Engineering Laboratory
- Sensor Optics Laboratory
- Thermal Infrared Multispectral Scanner
- Thermatic Mapper Simulator
- Zeiss Camera

Contact: Chuck Hill
Chief, Commercial Programs Branch
NASA/Stennis Space Center, Code HA31
Building 1100, Room 230
Stennis Space Center, MS 39529
(601) 688-2047, Fax (601) 688-1925

Sensor Engineering and Development Laboratory

This laboratory contains the following equipment:

- 10-inch off-axis collimator system (80-inch focal length)
- Visible/IR reference standards
- Scanning monochromator (0.3 to 13.0 m)
- 3-meter optical research bench
- Theodolite with autocollimator
- Fiberscope video camera and monitor
- CAE/IBM-AT PC board layout (D-size plotter)
- Class-1 clean bench
- Spectrophotometers (0.2 to 17.0 m)
- Vacuum station
- VIS/IR laser alignment system
- Electronic test/analysis equipment
- Calibrated standard lamp
- Electronic development system
- 20-inch integrating sphere (0.3 to 1.1 m)
- Fourteen-inch integrating sphere lab standard
- HP-85 Controller with X-Y plotter
- Breadboard focal plane analysis system
- Environmental chamber
- Blackbody calibration standard

Data Analysis Laboratory

The primary R&D production system is a Model 3200 MPS computer system from Concurrent Computer Corporation (formerly Perkin Elmer Data Systems Group). The system uses the OS/32 operating system with an 8-megabyte main memory and a 5800-megabyte disk memory.

Visiting Investigator Program (VIP)

The Visiting Investigator Program is designed to provide an opportunity for industry to utilize the specialized resources at Stennis Space Center (SSC). The VIP offers opportunities for various organizations and commercial entities to incorporate remote sensing technology into their operation. As a result, remote sensing technology is brought closer to the goal of commercialization.

The VIP was initiated in 1988 at SSC and has one or two VIP participants per quarter. SSC has acquired a remote sensing end-to-end micro-based data processing system that supports its commercialization effort.

Contact: David P. Brannon
Acting Deputy Director
Science & Technology Laboratory
NASA/Stennis Space Center, MS 39529
(601) 688-3326

Wallops Flight Facility

Operated by the Goddard Space Flight Center, the Wallops Flight Facility at Wallops Island, VA, is dedicated to suborbital research and includes a launch range and a research field. The 6,100 acres of the Wallops Flight Facility comprises three separate sections of property; the Main Base, the Wallops Island Launch Site and the Wallops Mainland. Wallops is responsible for projects using sounding rockets, balloons and aircraft that provide simple, flexible and inexpensive methods of conducting scientific investigations.

Sounding rockets carry scientific instruments hundreds of miles into space, while balloons are capable of carrying payloads of up to 6,000 pounds to altitudes of 30 miles. Aircraft at Wallops are used as platforms for instruments to collect data up to 40,000 feet altitude. In addition, mobile launch, tracking and data acquisition systems are transported to and operated at various world sites to accommodate sounding rocket, balloon and NASA networks mission requirements.

Wallops Flight Facility (continued)

In cooperative and commercial projects, Wallops provides support that includes launching, tracking aircraft flights and data reduction to various segments of DOD, other agencies and commercial and educational ventures.

Performance Testing Facility

- Spin Balance Facility-Dynamic
- Spin Balance Facility-Static

Launch Support Facilities

- Launch Pad 0
- Launch Pad 1
- Launch Pad 2
- Launch Pad 3
- Launch Pad 4
- Launch Pad 5
- Telemetry Station

Contact: H. Ray Stanley
Assistant for Commercial and
Tenant Programs
NASA/Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1479

Chapter 5: Facilities at the Centers for the Commercial Development of Space

There are some 175 industry partners and 55 university partners participating in NASA's Center for the Commercial Development of Space (CCDS) Program. The primary goals of the program are: to leverage and stimulate industry to consider space as a resource and an alternative to conventional R&D methods; and to stimulate commercialization through cost-effective transportation and infrastructure.

Supporting the development of technologies needed to define markets will stimulate the need for space transportation and infrastructure, which can be acquired in a conventional commercial way. NASA's grant program allows the CCDS's to develop in a totally commercial fashion with equipment, technology and supporting organization and transportation services. It establishes a focus that stimulates expansion in various focused discipline areas. It is expected that as markets mature, specific transportation systems and infrastructional services will be developing together.

NASA's Office of Commercial Programs has a signed fight agreement, called the Center for the Commercial Development of Space Flight Agreement, with each CCDS. This agreement serves to delineate all responsibilities, procedures and activities involved in the use of the Shuttle by the CCDS's, including provisions for Shuttle services at no charge. All projects are driven by industry needs. Any company interested in developing a joint payload may contact any of the sixteen CCDS's. (See additional listing of the CCDS's on pages 242 and 243.)

NASA Centers for the Commercial Development of Space (CCDS's)

Overview by Areas of Main Activities

Automation and Robotics

- Space Automation and Robotics Center (SpARC) – Environmental Research Institute of Michigan
- Wisconsin Center for Space Automation and Robotics (WCSAR) – University of Wisconsin

Remote Sensing

- Center for Mapping – Ohio State University
- Space Remote Sensing Center (SRSC) – Institute for Technology Development

Life Sciences

- BioServe Space Technologies – University of Colorado
- Center for Cell Research (CCR) – Pennsylvania State University
- Center for Macromolecular Crystallography (CMC) – University of Alabama at Birmingham (UAB)

Materials Processing in Space (MPS)

- Advanced Materials Center – Battelle Memorial Institute
- Center for Commercial Crystal Growth in Space (CMDS) – Clarkson University
- Consortium for Materials Development in Space – University of Alabama at Huntsville (UAH)
- Center for Space Processing of Engineering Materials – Vanderbilt University
- Space Vacuum Epitaxy Center (SVEC) – University of Houston

PRECEDING PAGE BLANK NOT FILMED

NASA Centers for the Commercial Development of Space (continued)

Overview by Areas of Main Activities (continued)

Space Power

- Center for Space Power (CSP) – Texas A&M University
- Center for the Commercial Development of Space Power and Advanced Electronics – Auburn University

Space Propulsion

- Center for Advanced Space Propulsion (CASP) – University of Tennessee

Space Structures

- Center for Materials for Space Structures – Case Western Reserve University

Advanced Materials Center/Battelle

Affiliation and Mission

The Advanced Materials Center, located at the Battelle Memorial Institute in Columbus, OH, was one of the first five CCDS's selected by NASA. Founded in 1985, the Center conducts research in advanced materials, including polymers, catalysts, electronic materials, metals, ceramics and superconductors. Opportunities for space commercialization are selected for study with the objective of improving the characteristics of the commercial product, improving the process by which the product is made, or gaining additional information about the material which could improve processing on Earth.

Focus

- Polymers – Key areas of emphasis include membranes, multiphase composites and plasma polymerization of thin films.
- Industrial Catalysts – Research is being conducted in the area of zeolites, mixed oxides and metal alloy catalysts.
- Electronic Materials – Research activities to date have been focused on growth of large cadmium telluride (CdTe) crystals.

In addition to the three major programs above, Battelle also is conducting research in other areas, including amorphous metallic catalysts, superconductor materials and hydrothermally grown crystals.

Achievements

Battelle's strength lies in its successful combination of research and flight programs. In April 1990, Battelle's polymer membrane experiment, Investigations into Polymer Membrane Processing (IPMP), flew on STS-31. Other membrane experiments are scheduled to follow. A zeolite experiment from Battelle's industrial catalyst program is being built for flight on the first U.S. Microgravity Laboratory (USML-1) mission in 1992. Two additional Shuttle experiments (solution growth of crystals and float zone growth of CdTe) are being developed for flights in the 1993-94 time frame. In addition to the Shuttle flight experiments, other polymer experiments are being conducted utilizing drop towers, experimental aircraft and sounding rockets.

Contact: Frank Jelinek, Director
Advanced Materials Center/Battelle
505 King Avenue
Columbus, OH 43201-2693
(614) 424-6376, Fax (614) 424-4065

BioServe Space Technologies

Affiliation and Mission

BioServe Space Technologies, headquartered at the University of Colorado in Boulder, is broadly oriented toward research and development in life sciences. BioServe combines expertise from the College of Engineering at the University of Colorado and the Division of Biology at Kansas State University, as well as expertise from over 30 participating industrial affiliates. Numerous projects are being conducted in biomaterials processing, biomedical testing during space flight, controlled ecological life support systems and development of enabling flight hardware.

Focus

- Biomaterials Processing
- Biomedical Models of Earth-borne Diseases
- Controlled Ecological Life Support Systems
- Hardware Development
  - AGBA (Autonomous Generic Bioprocessing Apparatus) for automated mixing in microgravity, which has flown successfully on sounding rockets
  - BIMDA (BioServe/Instrumentation Technology Associates, Inc. Materials Dispersion Apparatus) supports bioprocessing activities in space and is qualified for flight on the Shuttle Middeck
  - GBA (Generic Bioprocessing Apparatus) permits the use of a variety of methods for processing biological samples, including multiple mixing regimes, controlled incubation, real-time data acquisition, sample visualization and storage of processed materials
  - Plant lighting, nutrient delivery systems, containment control technology and advanced monitoring for Closed Environment Life Support System (CELSS) applications
  - Bioreactor development for waste management using cultivated microorganisms
  - Management of development of a re-entry system for COMET (COMmercial Experiment Transporter)

Achievements

BioServe has established a broad spectrum of life sciences research projects, including ground based models and controls. The CCDS also has flown numerous successful biomaterials processing experiments on NASA's KC-135 aircraft, testing effects of reduced gravity on hardware proposed for use in CELSS.

Contact: Marvin Luttges, Director
BioServe Space Technologies
University of Colorado/Boulder
Dept. of Aerospace Engineering Sciences
Campus Box 429
Boulder, CO 80309
(303) 492-7613, Fax (303) 492-8883

Center for Advanced Space Propulsion (CASP)

Affiliation and Mission

The Center for Advanced Space Propulsion is affiliated with the Calspan Center for Aerospace Research at the University of Tennessee. Its mission is to stimulate research in and contribute to those propulsion technologies considered prime in achieving the three basic flight mission objectives for the next few decades. These objectives are:

- Economic and reliable access to space and Space Station
- High-performance systems for lunar and interplanetary missions
- Effective means for transfers between Low Earth and Geostationary Orbits

Focus

- Advancing chemical propulsion
- Artificial Intelligence/expert systems and hypertext propulsion system applications
- Microgravity fluid management
- Electric propulsion systems
- Propulsion system laser materials processing

Achievements

Investigators designed and constructed hardware for a cryogenic fluids transfer experiment for flight on a KC-135. Ground experiments in 1990 successfully demonstrated the basic concepts and verified the computer code used in the design. Among other research, the Center also is testing an ion thruster in a vacuum facility.

The Center for Advanced Space Propulsion is responsible for program management of the COMmercial Experiment Transporter Program (COMET), a joint effort of the CCDS's.

Contact: George Garrison, Director
Center for Advanced Space Propulsion
University of Tennessee Space Institute
UT-Calspan Center for Aerospace Research
P.O. Box 1385
Tullahoma, TN 37388-8897
(615) 454-9294, Fax (615)455-6167

Center for Cell Research (CCR)

Affiliation and Mission

The Center for Cell Research was established at Pennsylvania State University in 1987. Its primary goal is to promote commercial life sciences space ventures by providing research expertise and access to NASA flights aboard rockets, satellites and the Shuttle.

Focus

The Center for Cell Research (CCR) investigators are working with pharmaceutical and biotechnology firms, instrumentation companies and lighting manufacturers to help them take advantage of the commercial opportunities the microgravity environment provides. CCR commercial partners receive spaceflight access, flight planning expertise, payload planning, access to flight-certified hardware plus ground-based research support.

Current CCR research programs include, but are not limited to:

- Defining the effects of microgravity on mammalian cells, tissues, organs and systems
- Establishing parallels between microgravity-induced effects and human disease on Earth
- Using the microgravity environment as an aid to separation and purification of valuable molecules, cells and subcellular particles
- Designing equipment for space-based life science research, development, testing and analysis
- Studying the effects of visible light on the immune and endocrine systems for applications in lighting design for human habitation in space and on Earth

Achievements

The Center for Cell Research and Genentech, Inc., of South San Francisco, CA, is conducting experiments aboard the Shuttle to investigate the biological changes caused by weightlessness and how closely those changes resemble Earth-based medical problems.

The Penn State Biomodule (see page 82), a robotic, minilab capable of testing eight biological samples automatically, was successfully flight-tested in 1990. The Biomodule is scheduled to be aboard a suborbital rocket flight every six months and is available for commercial projects.

Contact: Wesley Hymer, Director
Center for Cell Research
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407, Fax (814) 865-2413

Center for Commercial Crystal Growth in Space

Affiliation and Mission

The Center for Commercial Crystal Growth in Space is a consortium of universities, companies and national laboratories, founded in 1986 and managed by Clarkson University. The Center's main goal is to develop the technology for commercial growth of crystals in space. Such crystals have applications to high-speed integrated circuits, infrared sensors, optical communications and radiation sensors.

Focus

The Center for Commercial Crystal Growth in Space is organized into three teams, by growth technique:

- Vapor growth: cadmium telluride and mercury halides
- Solution growth: triglycine sulfate and l-alanine phosphate
- Melt growth: gallium arsenide, cadmium telluride and indium antimonide

The National Institute of Standards and Technology, one of the Center's members, characterizes crystals with high resolution short exposure X-ray topography on the National Synchrotron Light Source at Brookhaven National Laboratory.

Achievements

Projects at the Center have included:

- Discovery of additives to triglycine sulfate (TGS) that dramatically improve TGS's performance as an infrared sensor
- Discovery of additives to zeolite crystallization mixtures that greatly increase crystal size
- Development of improved mixing techniques and formulations for zeolite crystallization
- Automated hardware for zeolite crystallization in space
- Reproducible techniques yielding greatly accelerated vapor growth of high quality cadmium telluride crystals

Center for Commercial Crystal Growth in Space (continued)

Achievements (continued)

- Development of techniques for vapor growth of cadmium telluride in space
- An improved ampoule treatment technique for directional solidification of gallium arsenide
- Development of liquid encapsulated floating zone melting for growth of single crystal gallium arsenide
- Determination of factors influencing contamination of gallium arsenide by liquid encapsulants
- Elucidation of defects in undoped and indium-doped gallium arsenide
- Discovery that the major factor determining the stress level and dislocation formation in directional solidification is the degree to which the crystal sticks to its ampoule
- Measurement of contact angle and surface tension of GaAs and CdTe on various surfaces
- Determination of the gas circulation pattern in vapor growth of mercury halides
- Determination of the influence of g-level on directional solidification in a large human centrifuge

Contact: William Wilcox, Director
Center for Commercial Crystal Growth in Space, Clarkson University
Old Main, Room 126
Potsdam, NY 13676
(315) 268-2336, Fax (315) 268-6438

Center for the Commercial Development of Space Power and Advanced Electronics

Affiliation and Mission

The Center for the Commercial Development of Space Power and Advanced Electronics was established at Auburn University in 1987. The overall objectives of this Center are to identify the critical technological impediments to the economic deployment of power systems in space, advance these technologies and develop new products to meet the power generation, storage, conditioning and distribution needs. The goal is to provide quality power and reliability to the space customer by assuring that the products are space rated, cost effective, efficient, fault tolerant and autonomous.

Focus

The Center is taking the output from a variety of primary sources and providing the components and systems necessary for the efficient transmission, conditioning and distribution of electrical power in a space environment, in a form suitable to match the load requirements of commercial ventures in space and at costs which are commercially viable. This involves a synergistic interaction between space science, technology research and product development, not only to support these objectives, but also in the domain of component and system health maintenance.

Research areas include:

- Power distribution, control and management
- Power transmission
- Discrete power/energy storage sources
- Power conditioning
- Sensors, system reliability and parallel processing

Achievements

Each research project within the Center offers the promise of commercial potential. At the same time, complete systems are required for space power applications. This necessitates integration of all research areas in the program with the result being an overall technology focus.

Current research will provide the basis for developing complete power system packages, tailored to specific user needs. An example of this work deals with the design and fabrication of power conversion equipment. This project involves the investigation of candidate circuit topologies for specific applications to determine their impact on such issues as weight, efficiency, component stress and reliability.

Contact: Raymond Askew, Director
Center for the Commercial Development of Space Power and Advanced Electronics
Space Power Institute, Auburn University
231 Leach Center
Auburn, AL 36849-5320
(205) 844-5894, Fax (205) 844-5900

The Center for Macromolecular Crystallography (CMC)

Affiliation and Mission

The Center for Macromolecular Crystallography (CMC), established at the University of Alabama at Birmingham in November 1985, was among the first five CCDS's created by NASA. The goals of the Center are to develop the potential of the low-gravity environment of space for protein crystal growth research, to help its industrial, academic and governmental affiliates gain access to space, and to provide a variety of research capabilities in protein crystallography to industrial groups.

The wide range of services available through the CMC has made it possible for pharmaceutical, biotechnology and chemical firms to become more actively involved in commercial applications of macromolecular crystallography, an involvement that eventually will lead to commercial applications of protein crystal growth in space.

Focus

- To design and construct, in partnership with industrial affiliates, protein crystal growth hardware that will permit large-scale protein crystallization in microgravity on Shuttle missions
- To develop hardware that will permit protein crystal growth experiments in microgravity to be monitored and controlled in elaborate and automated detail on both Shuttle and freeflyer missions
- To conduct fundamental studies in protein crystal growth, including detailed studies of nucleation processes by laser light-scattering techniques; crystallization studies with various types of proteins; design and construction of prototype advanced protein crystal growth hardware that permits real-time monitoring of growth solutions; and research toward the design of automated protein crystal growth systems which permit dynamic control of crystallization processes
- To conduct crystallographic studies of proteins of basic importance to biomedical research, leading to practical applications of crystallography, particularly in the area of drug design and protein engineering

Achievements

Macromolecular crystallography is a powerful research tool in the pharmaceutical, chemical and biotechnology industries for drug design and protein engineering. Through a series of eight Shuttle flights during 1985-1990, the Center's protein crystal growth experiments have demonstrated that microgravity-grown crystals are larger, display more uniform structures, and yield X-ray diffraction data to significantly higher resolutions than the best crystals of these proteins grown on Earth.

Contact: Charles Bugg, Director
Center for Macromolecular Crystallography
University of Alabama at Birmingham
THT-Box 79
University Station
Birmingham, AL 35294
(205) 934-5329, Fax (205) 934-0480

Center for Mapping

Affiliation and Mission

The Center for Mapping, established at Ohio State University in 1986, conducts research in the areas of remote sensing and geographic information systems. Its main goal is to assist the U.S. private sector in the development of commercial remote sensing products and services.

Focus

This CCDS was created to address problems associated with the tremendous volume of remotely sensed data now becoming available, its compatibility with other types of data, its general utility and its marketability. The overall theme of the Center research projects is spatial digital data processing, however research projects can be broken down into five categories:

- Natural resource and farm management
  - design of a forest land use allocation model
  - development of an agricultural yield and production information system
  - establishing new criteria for gold exploration
- Digital image processing and computer vision
  - extracting three-dimensional information from aerial imagery and determining digital elevation models
  - developing strategies for dynamic, 3-D cartographic displays
- Satellite services
  - improving ocean routing using altimetry data
  - applying global positioning systems to transportation planning

Center for Mapping (continued)

Focus (continued)

- Disaster assessment
  - monitoring landslide hazard from snowmelt
- Energy and power production
  - determining feasibility of selected satellite applications to the gas and pipeline industry
  - integrating satellite, airborne and surface geophysics for global hydrocarbon exploration

Achievements

The Center for Mapping is developing a mobile workstation (i.e., mounted in a van) that combines satellite positioning signals with digital photographic images to automatically map and record crucial features of the nation's highways. The data and information generated from this workstation will be used by government transportation agencies to monitor road conditions and improve planning for highway maintenance. This research effort is expected to produce a range of commercial products. Moreover, it has the potential to revolutionize the data entry problem because the system can be mounted in airplanes, boats and other platforms and ensures the accuracy and homogeneity of digital data.

General Facilities

- Cray Y-MP/24 Supercomputer
- Digital VAX 8530
- Sun 3/150C-4-P5
- Intergraph 6000
- Intergraph 3050 (2)
- Apollo 4500
- Textronix 4129/DI-3000 3-D
- Trimple 4000SX GPS Receivers (5)
- Eikonix A80-A 4K x 4K Camera
- 80386 PC Image Processing/GIS Systems (3)

Contact: John Bossler, Director
Center for Mapping
The Ohio State University
1216 Kinnear Road
Columbus, Ohio 43212
(614) 292-6642, Fax (614) 292-8062

Center for Materials For Space Structures

Affiliation and Mission

The Center for Materials for Space Structures, established at Case Western Reserve University in 1987, is focused on providing materials which are capable of being processed in space and withstanding the space environment. In addition to their direct use in space structures, these new materials are being developed commercially for Earth-bound applications.

Focus

- Organic composites
- Metallic (aluminum and magnesium alloy) composites
- Low cost ceramic composites
- Inorganic and organic protective coatings
- Space structure material environmental stability

Materials are being developed for use in structures that will be made and/or assembled for use in the space environment.

Specific Requirements:
Key Applications of Low Earth Orbit Space Materials
a. Minimum of 30 Years Life
b. Environmental and Mechanical Attack
c. Mechanical Considerations
d. Thermal Fluctuations
e. Space Environmental Effects
f. Manufacturing Processes
g. Cost

Mechanical Properties of Interest:
Specific stiffness, specific strength, fracture properties, fatigue properties, thermal considerations, space environment materials degradation.

Space Flight Program

Materials produced by Center projects will be verified for space environment stability by testing on future space flights beginning in 1991 and continuing through 2005. The Space Flight Program concentrates on using existing and planned Space Transportation Systems to facilitate exposure of materials while reducing costs.

Center for Materials for Space Structures (continued)

Equipment

The Center for Materials for Space Structures currently houses the following equipment:

- JEOL-JSM-840A Scanning Electron Microscope
- Thermal Fatigue Testing Unit
- Variable Angle Spectroscopic Ellipsometer (VASE) (J. A. Woollam Company)
- ASTM E-595 Low Outgassing Test Service (McGhan Nusil performs this test as a service to the Aerospace Community. The company also supplies the CV24 Volatility Test Bench to companies wishing to purchase this testing apparatus.)
- RF Plasma Ashing Apparatus
- Infrared Spectrometer (Nicolet System 800)
- Acoustic Microscope
- Low-Voltage Scanning Electron Microscope Facility
  – Model JSM-840
  – Magnification range: 10x to 300,000x
- Thermal Fatigue Testing Unit Facility
  – Temperature Range: +250° F to -200° F

Achievements

The Materials for Space Structures at Case Western Reserve University maintains an extensive materials research program.

The Space Flight Program provides a cost-effective manner for industry, government and academia to access space for materials evaluation on a limited cost-share basis.

Contact: Eric Baer, Director
Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Avenue
Cleveland, OH 44106
(216) 368-4202, Fax (216) 368-3209

Center for Space Power

Affiliation and Mission

The Center for Space Power, established at the Texas A&M University in 1987, conducts research relevant to space power, and develops and demonstrates technology associated with the commercial use of space. Its goal is to demonstrate that providing power in space is an attractive commercial venture. Towards this end, the Center's objectives are to conduct research critical to the commercial success of industry and related to space power needs, stimulate technology interchanges and the training of space technology professionals, enhance educational programs and achieve economic viability independent of NASA funding.

Focus

The Center for Space Power sponsors research and product development in the areas of space power requirements, power generation and conversion, power system design, power conditioning and control, energy storage, power transmission, materials and thermal management.

Achievements

The Center for Space Power is developing flight experiments onboard the Shuttle to evaluate microwave power transmission, frozen startup of a heat pipe in microgravity, micro heat pipes, Rankine cycle power systems and solid polymer electrolyte fuel cells.

Contact: Alton D. Patton, Director
Center for Space Power
Texas A&M University
Wisenbaker Engineering Research Center
Room 223
College Station, TX 77843-3118
(409) 845-8768, Fax (409) 845-8857

Conduction Heat Transfer Laboratory

This laboratory consists of several high vacuum test facilities, in which steady-state thermal contact resistance tests can be conducted; a periodic contact resistance test facility for evaluating transient and periodic contact resistance; a guarded hot plate for making steady-state thermal conductivity measurements; and the facilities for testing and modeling a wide range of heat pipes, passive high conductance devices, utilizing the latent heat of vaporization for heat transfer.

The steady-state thermal contact resistance test facility is comprised of three test chambers with loading capabilities of 2,000, 1,000 and 100 pounds. The high vacuum systems allow measurements to be made in a wide variety of gaseous environments or under vacuum pressures as low as 10^{-8} torr.

Center for Space Power (continued)

The periodic contact test facility is used to evaluate transient and periodic contact resistance phenomena and provide information on the influence of the cycle period on other parameters that have an impact on the thermal contact resistance.

The guarded hot plate test facility is designed for a sample size ranging from two to three inches in diameter and a maximum power input of 100 watts.

Contact: L. S. Fletcher
Center for Space Power
Wisenbaker Engineering Research Center
Texas A&M University
College Station, TX 77843
(409) 845-7270

Tribiology Laboratory

This laboratory studies the compound and fretting wear characteristics of metals and alloys. Two wear machines are available for studying the interactions of forces, sliding velocities, impact frequencies and frictional characteristics of materials.

The equipment fits within a conventional laboratory setting. The compound wear tester occupies approximately 15 square feet and weighs about 700 pounds.

Contact: R.B. Griffin
Center for Space Power
Wisenbaker Engineering Research Center
Texas A&M University
College Station, TX 77843
(409) 845-1251

Center for Space Processing of Engineering Materials

Affiliation and Mission

The Center for Space Processing of Engineering Materials at Vanderbilt University was one of the five initial CCDS's established in 1985. The goals of the Center at Vanderbilt are to establish the technical feasibility and commercial potential of the space environment for materials processing research and manufacturing applied to high value-added engineering materials and highly leveraged Earth-based processes.

Focus

- Advanced thermal gradient processing technology for solidification processing of metals, alloys, semiconductors and oxide crystals
- Earth-based applications of the NASA/CCDS-developed containerless processing technologies for ultrapure materials and rapid solidification processing

Achievements

The Center has been allowed a composition-of-matter patent for a new permanent magnet material that significantly increases the resistance to demagnetization of magnets based upon alloys of platinum-cobalt. This development may induce the application of platinum-cobalt permanent magnets into entirely new series of devices.

The Center developed and is installing a pilot plant for coupling the proven benefits of rapid solidification processing with NASA/CCDS-developed containerless processing technologies. It is expected that this new facility will demonstrate significant processing advantages for many materials of industrial interest.

The Center is undertaking the development of a freeflying solar furnace for advanced thermal gradient processing of metals, alloys, semiconductors and oxide crystals. Evaluations are proceeding to demonstrate the technical feasibility of the unique approach, define the parameters of the space-based facility and illustrate the economics involved.

Contact: Tony Overfelt, Director
Center for Space Processing
of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7054, Fax (615) 322-7062

Consortium for Materials Development in Space (CMDS)

Affiliation and Mission

The Consortium for Materials Development in Space was established at the University of Alabama at Huntsville in 1985. Its mission is to stimulate investigations in space as a means to develop new materials and processes that benefit from the unique attributes of space. Projects rely on innovative applications of physical chemistry materials transport and their interactions.

Focus

- Commercial materials
- Commercial applications of physical chemistry and material transport
- Prompt and frequent experiments and operations in orbit

Achievements

Principal activities of the Consortium include physical vapor transport growth of highly non-linear optical inorganic and organic crystals and thin films; surface coatings and surface particle inclusions by electrodeposition; material preparations and longevity in hyperthermal atomic oxygen; physical properties of immiscible polymers and unique polymer production; and powdered meter sintering.

Another major activity undertaken by the Consortium is the first development of a material with a transition temperature to superconductivity above the temperature of liquid nitrogen. Researchers are evaluating the application of superconducting devices and circuits in commercial satellites cooled passively by thermal radiation to space.

The Consortium launched the first rocket requiring a Department of Transportation commercial launch license on March 29, 1989. The flight, called Consort-1, provided over seven minutes of low gravity for a variety of materials experiments. A second launch, Consort-2, did not achieve microgravity. However, a third launch, Consort-3, flew on May 16, 1990 and was considered very successful. Ten of the twelve microgravity experiments aboard operated as planned and offered results in the 14-minute flight that provided about seven minutes of microgravity.

Plans for a new series of longer duration low gravity flights are underway. The Joust series will provide between 13 and 15 minutes of low gravity, beginning in 1991.

Contact: Charles Lundquist, Director
Consortium for Materials Development in Space
University of Alabama/Huntsville
Research Institute Building
4701 University Drive
Huntsville, AL 35899
(205) 895-6620, Fax (205) 895-6791

Space Automation and Robotics Center (SpARC)

Affiliation and Mission

The Space Automation and Robotics Center (SpARC) (formerly, the Center for Autonomous and Man-Controlled Robotic and Sensing Systems) is located at the Environmental Research Institute of Michigan, in Ann Arbor, and is affiliated with the University of Michigan.

SpARC's goal is to be the nation's premier center to promote and facilitate the development and application of space-related automation and robotics technologies by U.S. industry.

Focus

- Promotion of space automation and robotics technologies; maintain and disseminate information on all aspects of space automation and robotics technologies; and promote an appropriate environment for the propagation and utilization of these technologies by networking and collaborating with U.S. industry, NASA and other organizations and individuals in related areas
- Development of automation and robotics technologies; initiate and conduct major projects with U.S. firms and other NASA Centers to link and integrate the components of space automation and robotics technologies and extend their boundaries
- Provide a complete range of services to help U.S.-based companies in selecting, adapting and applying appropriate space automation and robotics technologies to solve particular problems and gain a competitive edge

SpARC focuses on the following technologies:

- Tele-sciences (robot-control, tele-robotics and perception and information assimilation), artificial intelligence (particularly distributed AI), knowledge-based systems, machine learning and expert systems), computer vision and signal interpretation, human interfaces, mobile robots and system integration

Space Automation and Robotics Center (SpARC) (continued)

Focus (continued)

Possible application areas include: manufacturing automation, material processing, pharmaceuticals, environmental restoration/waste management, medical imaging, earth resource applications, geographic information systems, service robotics, satellite communication, intelligent vehicles, Mars & lunar missions and space stations.

Achievements

SpARC has initiated more than twenty projects, many of which have been completed successfully, including:

- Design For On-Orbit Spacecraft Servicing (DFOSS) Handbook
- Development of a photo-bioreactor and green cell lines for Closed Environment Life Support System (CELSS)
- Space Technology Education Program (STEP)
- Tele-Autonomous Multiple Arm Control and System Infrastructure
- Optical estimation of absolute spatial positions of a robot
- Tele-perception concept development

Contact: Ramesh Jain, Director
Space Automation and Robotics Center
Environmental Research Institute
of Michigan (ERIM)
P.O. Box 8618
Ann Arbor MI 48107-8618
(313) 994-1200 x2457, Fax (313) 665-6559

Space Remote Sensing Center (SRSC)

Affiliation and Mission

The Space Remote Sensing Center is a division of the Institute for Technology Development (ITD) and is located at the NASA/Stennis Space Center in Mississippi. Its objective is to provide commercial technology applications development of satellite remote sensing, image processing and geographic information systems.

Focus

Through its close relationship with Stennis Space Center, numerous universities and private organizations, and other government agencies, this CCDS is exploring ways to increase the operational productivity and efficiency of professionals involved in land planning and resource management through the utilization of remote sensing images and data.

Achievements

The Space Remote Sensing Center conducts an applications development program aimed at end users and a technology innovations program aimed at the valued-added services and support industry. This program is creating advanced techniques for agriculture crop monitoring, forest mensuration, environmental assessment, facilities monitoring and land use planning. Economic benefits are gained directly from improved operational planning, which can lead to lower project cost.

The Center has been designated as the official support center for the U.S. Army Corps of Engineers Construction Engineering Research Laboratory's software package called Geographic Resources Analysis Support System (GRASS). The geographic information and image processing system was ported to the Apple Macintosh II personal computer through the Center's Apple Developer partnership. This has enabled many potential users of remote sensing and geographic information to access this data on a low-cost system. An example of this effort is the development and presentation of a short course in the use and applications of MacGRASS 3.1, which includes lectures, individual tutorials and extensive hands-on experience.

Consulting Capabilities

- Image data processing
- Geographic Information System (GIS) applications
- Specialization in forestry, agriculture and other Earth resources

Data Processing Facility

- MASSCOMP 6650, 5600 and 5450
- Apple Macintosh
- Astronautics ZSI mini-super computer
- Colcomp and geophysics digitizer tables
- Matrix camera
- Image processing workstations (5)
- VerseTec wide-bed plotter

Contact: George May, Director
ITD Space Remote Sensing Center
Building 1103, Suite 118
NASA/Stennis Space Center MS 39529
(601) 688-2509, Fax (601) 688-2861

Space Vacuum Epitaxy Center (SVEC)

Affiliation and Mission

The Space Vacuum Epitaxy Center, established at the University of Houston in 1986, is unique in its focus on the ultra-vacuum aspect of space for materials processing and purification.

Major research efforts are in the areas of definition of epitaxially-grown compound semiconductor materials for enhancement under space ultra-vacuum conditions; and the definition and development of superconducting epitaxially grown films with Low Earth Orbit space-enhanced characteristics.

Focus

- Adaptation of the Molecular and Chemical Beam Epitaxy (MBE/CBE) process to space
- The production of new electronic, magnetic and superconducting thin film materials and devices as well as materials purification in terrestrial laboratories and space for commercial exploitation
- The development of commercial space hardware (for example the Wake Shield Facility) for research and development and enhanced access to space

Current Research and Development activities include:

- CBE Growth of Compound Semiconductors
- MBE Growth of High-T_c Materials
- MBE Growth of InGaSb/InAs Superlattices
- Induced Magnetic Field Quantization in Low-dimensional Systems
- Atomic Layer Epitaxy of InGaSb/InAs SLS
- Surface Science of High-T_c Materials
- STM Studies of Ge/Ge and Ge/GaAs
- RHEED Studies of MBE Growth Kinetics
- Laser Deposition of High-T_c Materials
- Disordered Superlattice Studies
- MOCVD Growth of High-T_c Materials
- Wake Shield Facility Development

Achievements

The Center is placing major emphasis on helping to increase access to, and utilization of, the space ultra-vacuum. This ultra-vacuum can be achieved by deployment of a Wake Shield Facility (WSF) in a Low Earth Orbit. SVEC and Space Industries, Inc., of Houston, TX, are jointly developing the flight hardware for the Shuttle-deployable Wake Shield Facility.

Researchers expect the disk-shaped wake shield to produce an ultra-vacuum in the order of 10^{-14} torr in its wake. The first experiment, scheduled for flight on the Shuttle in 1993, will go as a freeflyer, allowing the facility to have about sixty hours of freefly epitaxial growth runs before being retrieved by the Shuttle's Remote Manipulator System. The experiment will include GAS canisters as part of the WSF structure. These "Smart Payload Canisters" will provide on-board command and control as well as power.

Contact: Alex Ignatiev, Director
Space Vacuum Epitaxy Center
University of Houston
Science & Research Building I
4800 Calhoun Road
Houston TX 77204-5507
(713) 749-3701, Fax (713) 747-7724

Wisconsin Center for Space Automation and Robotics (WSCAR)

Affiliation and Mission

The Wisconsin Center for Space Automation and Robotics was established at the University of Wisconsin in 1986. Its mission is to conceive, demonstrate and stimulate commercial opportunities in automation and robotics technology for use in space for Astrobotics™, Astroculture™ and Astrofuel™.

Focus

The Center's three-prong program is focused as follows:

- Astrobotics™ – automation and robotic technologies for performing functional tasks required of humans to live, travel and explore in space
- Astroculture™ – agriculture technologies for the production of food supplies and waste recycling to support humans' existence in space
- Astrofuel™ – acquisition of helium-3 (He-3) from lunar and planetary sources for supplying fusion energy for use on Earth and in space travel

Achievements

The Wisconsin Center for Space Automation and Robotics conducts research in laboratory facilities throughout the University of Wisconsin/Madison campus. Talent is drawn from university faculty and staff in engineering, agriculture, medicine and the physical sciences, together with industrial consortium members.

Since its inception, WSCAR has achieved the following accomplishments:

- High performance grippers and intelligent grasping units
- Robot finger tip force and torque sensors
- Telerobotic performance analysis system
- Adaptation of technologies for the physically impaired
- Humidity control and water recovery system
- Plant lighting system based on LEDs
- Water and nutrient delivery system for plants
- Completion of a lunar He-3 resource assessment
- Study of environmental effects of He-3 recovery from the moon
- Analysis of the financial factors governing the profitability of a lunar He-3 venture
- Equipment and operational concepts for recovery of volatile materials from lunar regolith

Contact: John Bollinger, Director
Wisconsin Center for Space Automation and Robotics
University of Wisconsin
1357 University Ave.
Madison WI 53715
(608) 262-5524, Fax (608) 262-6707

Chapter 6: Other Ground-Based Facilities

In addition to NASA and the Centers for the Commercial Development of Space, several companies and universities have identified facilities which are available to other users. Included along with specific items of hardware are "clean rooms" and other facilities which form a necessary step in fabricating and testing a unit of space flight hardware.

Acoustic Thermal Test Facility (ATTF)

This test facility can be used to test spacecraft, space vehicles or structures requiring space systems cleanliness levels and environmental standards. It offers the largest integrated high-intensity acoustic and temperature cycling chambers now in operation.

Acoustic Thermal Test Facility – Main Structure

Dimensions:	130 ft x 80 ft x 60 ft H
Square footage:	10,000 ft^2
Overhead crane:	10-ton traveling bridge crane
Main Control Room:	41 ft x 46 ft
Main entry:	30 ft x 50 ft H
Building conditioning:	Class 100,000 clean room

Buildup/staging area
Security/controlled access

Acoustic Chamber

Dimensions:	33 ft x 40 ft x 50 ft H
Volume:	65,000 ft^3
Frequency range:	25 to 10,000 Hz
Sound pressure level:	154 dB
Data acquisition:	200-Channel Digital Acquisition System

22,000 Gal Cryogenic Tanking Abilities

Thermal Chamber

Dimensions:	30 ft x 31 ft x 50 ft H
Volume:	46,500 ft^3
Temperature range:	-40° F to +185° F with humidity control
Temperature rate change:	1° F/minute
Data acquisition:	200-Channel Graphic Display/Plots

Contact: D. A. Nirschl, Director
Test and Evaluation, MZ 23-8370
General Dynamics Space Systems Division
P.O. Box 85990
San Diego, CA 92186-5990
(619) 573-999

Antenna Test Facilities

Range length is 1,700 feet.

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

PRECEDING PAGE BLANK NOT FILMED

Assembly and Integration Facility

Certified clean area – 4,000 ft^2
Storage area
General work area
5-ton bridge crane (2)
7 1/2-ton gantry crane
Optical alignment system
Assembly and flight hardware handling equipment

Contact: Karole G. Monks
Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807-5301
(205) 726-5613

Environmental Test Facilities

Static Load Test Facility
Vibration Test Facility
Space Simulation Facility
Space Chamber

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Ground-Based Containerless Processing Facility

The Intersonics' laboratory equipment can be reconfigured and optimized for various materials. The multidisciplinary team at this facility is engaged in equipment development and containerless property measurement and processing research. The laboratory presently operates a 5 kW electromagnetic levitator (pressures from high vacuum to 2 Bar), two aerodynamic levitators (with gas mixture handling), a prototype high pressure acoustic levitator and a breadboard high temperature acoustic levitator. The high temperature acoustic levitator is equipped with xenon-arc lamp beam heating and can be used onboard the KC-135 aircraft. The facility includes a 300 W CO_2 heating laser and a 100 W, 2.45 GHz microwave generator for processing or heating, a tunable dye laser for laser-induced fluorescence analysis, a mass spectrometer for gas analysis, a laser polarimeter for optical property measurement and pyrometers for temperature measurement.

Contact: Richard Weber or Robert Schiffman
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772

Satellite Assembly and Test Facilities

Class 10,000 clean room

11.9-meter diameter thermal-vacuum chamber

High-bay class 1B area

Class 100,000 clean room-final integration with a KR-85 leak tester

Anechoic chamber

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Space Hardware Environmental Qualification and Testing Facilities

This facility provides ground-based and space flight hardware environmental qualification testing and analysis.

A partial list of environmental qualification analyses/tests available includes:

- space flight-acceleration (high/low frequency and on-orbit)
- on-orbit load, random vibration, shock, vibroacoustics, thermal vacuum, operational and non-operational environments, i.e., temperature, pressure, humidity
- Transport/storage packaging-temperature pressure humidity, fungus, salt spray, rain, hail, snow, solar radiation, ozone, sand/dust, vibration, handling shock

Contact: Robert A. Hall, Manager-Space Programs
Wyle Laboratories
P.O. Box 1008
Huntsville, AL 35807-5101
(205) 837-4411

Space Simulation Chamber/Laser Diagnostics

Cylindrical Vacuum Chamber (9 ft diameter x 20 ft long)

- 2 kw helium refrigerator
- 2 stage helium compressor
- LN_2 Heat Shield and gaseous He finned array
- Two 16" cryopumps/mechanical and diffusion pumps
- Vacuum Instrumentation
- Optical Quality Ports

Power Supplies/Instrumentation for Testing Electric Thrusters and Performing Plasma Diagnostics

Laser Systems

- Subpicosecond Laser System
- Picosecond Excimer Laser
- CO_2, Argon Ion, Tunable Dye, Nd:YAG, HeNe

Computer Systems

Image Analyzers

Contact: George W. Garrison, Director
Center for Advanced Space Propulsion
University of Tennessee/Calspan
P.O. Box 1385
Tullahoma, TN 37388
(615) 454-9294

Space Simulation Chamber/Pulsed Power Facility

Cylindrical vacuum chamber
(1.8 m diameter x 2.4 m L)

Energy storage system for pulse testing

Allen-Bradley computer

IBM-PC-AT computer

Contact: D. A. Fikse, Manager
Electromagnetic Applications
Westinghouse Science and Technology Center
1310 Beulah Road
Pittsburgh, PA 15235-5098
(412) 256-2312

Subsystems Test Facilities

Three-axis Servo Table

Class 100,000 laboratory

Battery/cell test area

Solar Array facility

Electromagnetic Compatibility/interference facilities

Contact: T.A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Sycamore Canyon Hazardous Test Facility

The Sycamore Canyon test facilities can be used for large scale cryogenic tests and limited ordnance testing deemed too hazardous for metropolitan areas. It offers various sizes LH_2 test stands, remote block houses and personnel experienced in hazardous test operations. These facilities offer:

Liquid hydrogen testing combined with other environments
Liquid nitrogen testing
Cryogenic proof and burst testing
Cryogenic cycling tests
Cryogenic vacuum testing
Other hazardous propellants considered
Leak testing
Flow testing
Large-scale structural testing
Staging ordnance testing
Small SRM test firings
Instrumentation landlines
Security

Contact: D. A. Nirschl, Director
Test and Evaluation, MZ 23-8370
General Dynamics Space Systems Division
P.O. Box 85990
San Diego, CA 92186-5990
(619) 573-9991

Underwater Test Facility (UWTF)

The Underwater Test Facility is a large, optically clear tank of water used to conduct neutral-buoyancy simulation of the weightless environment encountered in space. Experiments, in either EVA or IVA mode, addressing assembly, maintenance or repair of hardware elements, can be performed in the tank. Extravehicular Mobility Units (EMU Space Suits) are available to support EVA simulations. A high-fidelity full-scale Shuttle cargo bay mock-up is used to support experiments associated with Shuttle payloads. Underwater video cameras are used for data acquisition and assessment of operational procedures. Full duration EVA or IVA proposed tanks can be simulated by the use of neutral buoyancy techniques in the tank. The tank also can be used for other hardware development or test activities requiring a large, environmentally controlled body of water.

Operational Characteristics

Dimensions:	70 ft diameter x 36.5 ft deep, in ground
Volume:	approximately 1 million gallons of water
Overhead Crane:	5-ton capacity
Water:	Optically clear and thermally conditioned
Data Acquisition:	Audio and video

Contact: D. A. Forge or A. W. Maddox
McDonnell Douglas Space Systems Co.
MS 38-2
5301 Bolsa Avenue
Huntington Beach, CA 92647
(714) 896-5544

Lujan Center for Space Telemetering and Telecommunications Systems

The mission of this Center is to support the development of technology for space-based telemetering and telecommunications systems through research, consulting and educational activities. Research areas include:

- Bandwidth-efficient coding and modulation techniques
- Packet telemetry protocols and processing
- Optical communications
- Digital image processing

The Center has laboratories for:

- Design of communications hardware
- Optical communications
- Computer-based simulation and modeling

Contact: Frank Carden, Director
New Mexico State University
Box 30001, Dept. 3-0
Las Cruces, NM 88003-0001
(505) 646-3012, Fax (505) 646-3549

Physical Science Laboratory

The mission of this facility is to design, fabricate and test space-qualified support hardware with particular emphasis on microcomputer-controlled systems, high voltage power supplies, altitude control systems, and electronic data and telemetry systems. The lab is especially applicable to commercial developers who are utilizing Get-Away Special (GAS) canisters, SPARTAN carriers, satellites, rockets or balloon-borne systems. Activities also include operational and program management support.

Contact: Bernard M. McCune
Chief, Space Payload Section
Physical Science Laboratory
New Mexico State University, Box 30002
Las Cruces, NM 88003-0002
(505) 522-9100, Fax (505) 522-9434

Solar Furnace Facility

- 90.25 ft^2 flat heliostat
- 5-ft diameter parabolic concentrator
- 192-ft^2 data acquisition and office building
- HP-87 computer

Contact: Dan O'Neil
Georgia Tech Research Institute
Atlanta, GA 30332
(404) 894-3589

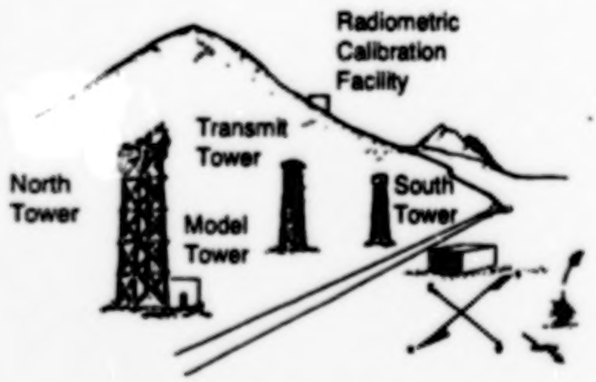
Physical Science Laboratory Outdoor Antenna Range

The Antenna Range is a free space elevated range, centered around three principal towers. These towers are of wooden construction, about 82 feet tall, with elevators for lifting large heavy structures (up to 700 pounds). The towers are arranged in a line with the central tower about 320 feet from the north tower and 160 feet from the south tower. Each tower has an associated control building which contains a receiver, chart recording equipment and positioner control console.

To facilitate small antenna design and development efforts, a model tower is elevated 35 feet and 130 feet from the center tower. The model range tower tilts 90 degrees for easy access to the positioner head, which rotates a full 360 degrees. The tower rotates a full 360 degrees and is capable of lifting 200 pounds.

Additional range legs are provided from the central tower. An auxiliary remote illuminator tower is located on a hillside about 3,000 feet away. Concrete pads are available for placing positioners 1,500, 2,200 and 3,000 feet away from the center tower. Many standard elevation, azimuth and polarization positioners are available for antenna system testing. Many of these positioners can be mounted on either the 82-foot towers or any of the additional range legs. A very large positioner suitable for ground operation also is available. It can accommodate up to 40,000 pound devices with moments up to 600,000 foot-pounds.

Contact: Bernard M. McCune
Chief, Space Payload Section
Physical Science Laboratory
New Mexico State University, Box 30002
Las Cruces, NM 88003-0002
(505) 522-9100, Fax (505) 522-9434



Chapter 7: Airborne Facilities

Aircraft and balloons provide the opportunity to conduct research related to remote sensing, climatology, microgravity and other activities. NASA supports these activities with aircraft flown from three NASA Centers: Ames Research Center, Wallops Flight Facility and Stennis Space Center; and with balloons supported by Wallops.

Like satellites, airborne instruments observe atmosphere, ocean and land. However, unlike satellites, airborne instruments are available for modification. Virtually all satellite-borne sensors used in Earth sciences were developed first as airborne instruments.

Airborne facilities that provide microgravity environments for limited periods of time include sounding rockets, aircraft with parabolic flight paths and high-altitude balloons. The use of these facilities may be considered an interim step between ground-based and space-based research; or it may serve as a cost-efficient opportunity to test out a theory. Both experiment design and hardware construction also may be tested in the limited capacities of airborne facilities. (Note: Sounding rockets are described in Chapter 20.)

Balloons

Balloons provide platforms that carry payloads with scientific instruments to make measurements at altitudes of up to 30 miles. They provide much longer flight times than sounding rockets, without the rigors of rocket liftoff, vibration and g-forces, permitting laboratory-quality equipment to be flown.

Balloons are made of thin, polyethylene material .8 mil thick and up to 30 million cubic feet in volume at full inflation. Historically, the thickness ranges from 0.5 mil to 1.5 mil and up to 50 million cubic feet in volume. Payloads up to 5,500 pounds can be accommodated and flight durations may vary from one to 60 hours. A new capability in the form of long-duration flights of several weeks or months is under development. A tethered balloon system also is used and can carry a 400-pound payload to a one-mile (5,280 ft.) altitude. High-altitude balloons can provide up to a minute of microgravity for experiment payloads.

Capabilities and benefits for scientific research that cannot be duplicated by other methods are possible. Use of balloons offers measurements in areas too low for sounding rockets or satellites and too difficult for aircraft which cannot sustain flight for long periods or reach the required heights. Payloads may be recovered for reuse of instruments and data-gathering. Balloons allow for multidisciplinary experiments, vertical profile measurements at a specific altitude at a specific time, or measurements at multiple locations over a particular time period. They also allow for satellite data verification using systems launched in coordination with orbital coverage and for flight testing of materials, instrumentation and experiments destined for future space missions.

Balloon-Borne Drop Capsule MIKROBA

This microgravity facility is filling the gap between drop-towers and parabolic flight missions on one hand and sounding rockets on the other. The drop capsule is attached to a stratospheric balloon and carried up to altitudes of between 40 and 46 km. After reaching the operational altitude, the capsule is released via telecommand. During the free fall, microgravity conditions are realized inside the MIKROBA capsule. The increasing aerodynamic drag is compensated by a controllable cold gas thrust system. Up to 60 seconds of microgravity in the region of 10^{-3} g are achieved. Parachute activation at an altitude between 20 and 14 km terminates the period of microgravity and guarantees a soft landing. The capsule is returned to the launch site by helicopter or car.

After cut-off of the MIKROBA capsule from the balloon, the g-level switches from 1 g to nearly zero g. During increasing airdrag the thrust compensation keeps the g-level at $+/-10^{-3}$ g.

Operational Characteristics

Microgravity period:	about 60 seconds
Duration of ascent:	up to 4 hours
Atmospheric environment at ceiling:	p ~ 2HPa T ~ 250 K
Maximum velocity:	approx. Mach 2.4
Maximum load during parachute inflation:	up to 7 g
Final descent:	below 7 m/s
Total capsule envelope:	6.00 m total length; 0.45 m outer diameter; 500 kg total mass (maximum)
Payload envelope:	2.00 m length; 0.42 m diameter of experiments; 200 kg payload mass

Telemetry/Telecommand

Downlink (Data):	128 KBits/s
Uplink (Commands):	Up to 14 telecommands can be routed to experiments

Typical Experiment Data

Platform diameter:	0.42 m
Experiment length:	approximately 0.60 m
Experiment weight:	approximately 40 kg
Battery package:	10 Ah/28 V, Battery packs can be combined to satisfy larger power requirements

Data acquisition

Analog data:	32 channels
Signal level:	+/-10 V
Resolution (word length):	12 bit
Sampling rates:	781.8 words/s 381 words/s 95 words/s 6.61 words/s
Digital data:	36 channels

Available: Now

Contact: James L. Rand
Winzen International, Inc.
12001 Network Blvd., Suite 200
San Antonio, TX 78249
(512) 692-7062

NASA Balloon Program

Wallops Flight Facility in Virginia manages the NASA Balloon Program, including management of NASA's National Scientific Balloon Facility (NSBF) in Palestine, TX. Through NSBF, Wallops provides balloons, helium and operational support for launches from many sites, including Palestine, TX; Fort Sumner, NM; Holloman Air Force Base, NM; Laramie, WY; Barking Sands, HI; Poker Flat Research Range, AK; Ainsworth, NE; Wallops Island, VA; and from foreign countries such as Australia, Canada and Brazil. Wallops provides the technical direction of the program, the research and development support, and selected tracking and data acquisition and processing. The Balloon Program supports about 50 launches a year with an overall success rate of about 85 percent.

Available: Now

Contact: H. Ray Stanley
NASA/Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1479

StratoFilm Free Floating Balloons

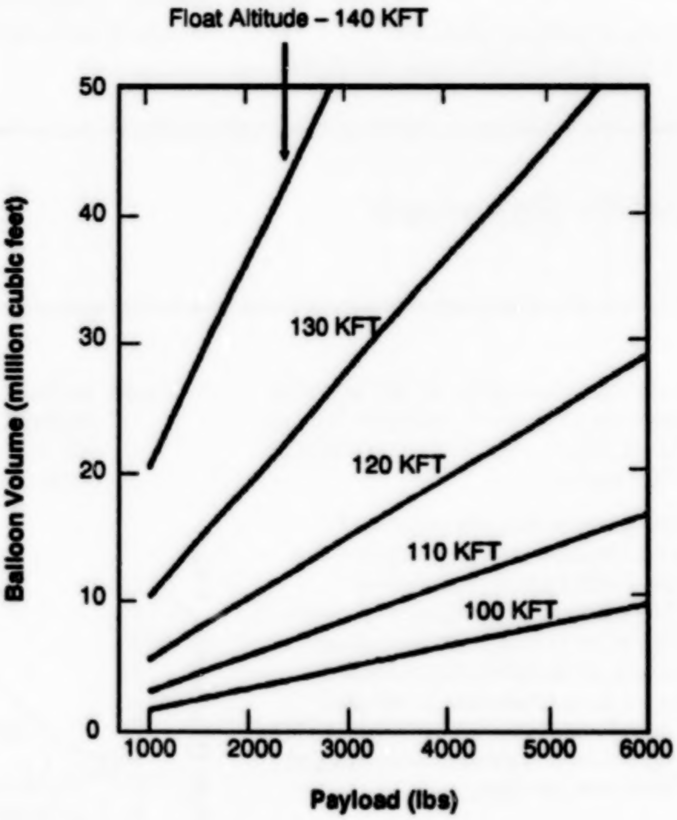
StratoFilm is a uniquely formulated polyethylene thin film that will remain ductile at temperatures below -90° C even when extruded to thickness less than 12 microns (.5 mil). When this film is used in conjunction with stringent quality control techniques and patented table designs, a family of balloons may be manufactured with a 100-percent flight success record. These stratospheric platforms are routinely used to carry payloads up to 7,000 pounds and have reached altitudes in excess of 170,000 feet. Typical applications include atmospheric sampling, ozone observation and cosmic ray research, as well as various astronomical observations.

Proven design techniques for the "natural shaped" balloon result in a system which may stay aloft for several days with the use of a variety of ballasting techniques. These systems may be quite large with gore lengths routinely exceeding 600 feet. When launched from the ground, the lifting gas will occupy less than one percent of the volume of the balloon. As the balloon ascends to its designed altitude, the gas expands to completely fill the balloon and vent any excess gas. StratoFilm balloons have been flown successfully from Antarctica to Canada and Sweden.

New balloon systems are being developed for longer duration missions. The unvented "superpressure" balloon is designed to remain aloft for one year. A unique manufacturing technique has been developed that permits the payload capacity to increase to be comparable to "natural shaped" balloons in the future. The Engineering Division is available to design a unique system for virtually any payload and altitude requirement.

Available: Now, with newer models under development

Contact: James L. Rand
Winzen International, Inc.
12001 Network Boulevard, Suite 200
San Antonio, TX 78249
(512) 692-7062



Aircraft

Helicopters and aircraft provide a variety of flight performance and payload-carrying ability. Research missions are conducted locally and on a regional or global basis. Helicopters offer support for small scientific instrument packages which need to operate at low speeds and low altitudes. Large turboprop aircraft can carry payloads of more than 10,000 pounds and often are deployed to underfly satellites and/or study phenomena peculiar to specific sites.

The traditional use of research aircraft has set the pace for progress in several areas of the atmospheric sciences, such as air flow dynamics, air chemistry, radiation and cloud/aerosol physics, and air pollution. The capability of conveying a variety of sensors to critical parts of the atmosphere to make in situ measurements has allowed fundamental discoveries concerning how physical quantities correlate with stormy and quiescent conditions. Such observations can be compared with data from surface-based or satellite-borne remote sensors. In one scenario, the aircraft may measure the same quantity as the remote device, thus providing a calibration of remote-sensing technology, or it may measure quantities which cannot be determined remotely.

The aircraft's ability to carry sophisticated remote-sensing instruments to the region of interest, for a carefully planned study or a quick observation of newly developed phenomena – such as a storm, a volcano, a polluted basin, a region of sea ice, drought-stricken crops, a warm ocean current or a forest fire – together with its ability to remain on station several hours, makes it an ideal platform for gathering data.

Three types of aircraft generally are used for microgravity experiments, the KC-135, the F-104 and the Learjet. They all achieve temporary states of microgravity by flying parabolic flight patterns. During the free-fall period, gravitational effects in the range of 10^{-2}g can be obtained. In most cases, parabolic trajectories are repeated so that several periods of weightlessness are possible. The typical time lead for scheduling experiments varies between one and six months, depending upon the nature of the experiment and aircraft availability.

NASA encourages commercial developers to fly with their payloads to operate the experiments and observe the results as they occur. An alternative to direct user involvement is provided by Payload Systems, Inc., of Cambridge, MA, who performs turnkey operations for its clients, including payload integration and operations.

Microgravity Research

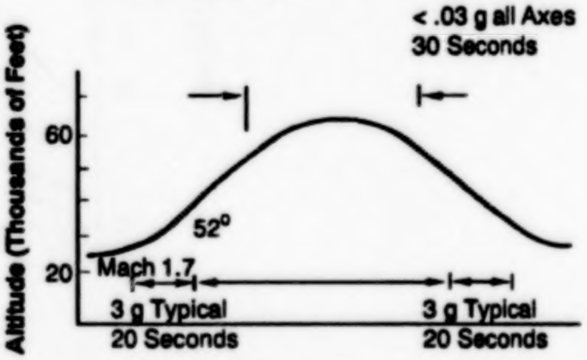
F-104

The F-104 is a modified supersonic, 2-man jet fighter. By flying in a parabolic trajectory between 25,000 and 65,000 feet, it is capable of a variable low-g period of approximately 60 seconds.

The experimental package must be capable of surviving a 3-g acceleration and is restricted in size and weight by the F-104's small experimental compartment. The equipment is limited in volume to an area 10 inches by 15 inches by 21 inches and in weight to 35 pounds. All equipment is restrained during flight and not accessible after 30 minutes before takeoff; therefore, all experiments must be fully automated except for on-off functions and limited to one parabolic maneuver per flight.

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



Low G Time: <.1 g – 60 Seconds
<.03 g – 30 Seconds

KC-135 Aircraft

The KC-135 can simulate up to 40 periods of low-gravity for 25-second intervals during one flight. The aircraft accommodates a variety of experiments and is often used to refine space flight experiment equipment and techniques.

The KC-135, like other microgravity research aircraft, obtains weightlessness by flying a parabolic trajectory. The plane climbs rapidly at a 45-degree angle (pull-up), slows as it traces a parabola (pushover) and then descends at a 45-degree angle (pull-out). The forces of acceleration and deceleration produce twice the normal gravity during the pull-up and pull-out legs of the flight, while the brief pushover at the top of the parabola produces less than 1 percent of the Earth's gravity.

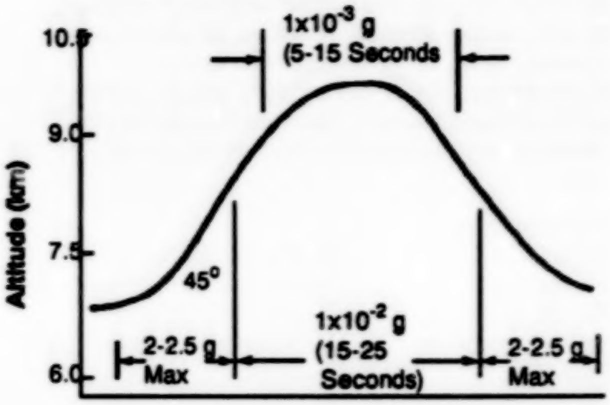
The KC-135 flies its 40 parabolic trajectories between 7.32 and 30.37 kilometers. The KC-135 is located at Johnson Space Center in Texas.

Operational Characteristics

Bay dimensions:	3.04 m x 16.4 m
Bay overhead clearance:	1.8 m
Maximum floor loading:	90 kg per 0.09 square meters
Acceleration:	2.5 g
Microgravity duration:	25 seconds
Number of maneuvers/flight:	40

Available: Now, with advanced scheduling

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



Learjet

The Learjet Model 25 aircraft provides investigators with a cost-effective way to conduct and observe experiments in simulated microgravity. The aircraft allows 18 to 22 seconds of 0 g, (10^{-2} accuracy*) and somewhat longer times at other selected reduced gravity levels.

The Learjet, like other microgravity research aircraft, achieves weightlessness by flying a Keplerian trajectory. Starting with maximum forward velocity, the aircraft is positioned 50 to 55 degrees nose high (2.0 to 2.5 g pull up). At this point the x, y and z axis are zeroed and maintained until the aircraft reaches approximately 30 degrees nose low.

Cabin cross-section is 52 inches high and 48 inches wide and approximately 6 feet of length is available for experiment use. Although not required, research apparatus is normally mounted in Lewis-furnished instrument racks (maximum of 2) with dimensions of 35.75 inches high x 20.75 inches wide x 24 inches long. Experiments mounted in these racks are limited to 188 pounds maximum weight and 3,272 in pounds overturn moment.

Operational Characteristics

Bay dimensions:	48 in x 72 in
Bay overhead clearance:	52 in
Acceleration:	Pull up: 2.5 g Pull out: 2.5 g
Microgravity accuracy:	10^{-2} Gz*
Microgravity duration:	22 seconds
Number of maneuvers/flight:	6

** Measured and recorded on each trajectory ("x" and "y" axis of comparable or better quality for the entire trajectory)*

Available: Now

Contact: NASA/Lewis Research Center
Aircraft Operations
21000 Brookpark Road, MS 4-2
Cleveland, OH 44135
(216) 433-2023

Remote Sensing Research

C-130B, Lockheed

A suite of sensors is provided for use on this multi-purpose remote-sensing platform, including weather radar, radar altimeter, closed-circuit television and data acquisition used for hydrological, ecological and geological research, climate research, oceanography, land processes and sensor development. The C-130 supports geologic, ecologic and hydrologic research, ocean and scatterometer research, wetlands studies and biomass combustion work.

Performance

Altitude:	25,000 feet (max)
Range:	2,200 nautical miles
Duration:	8 hours at 22,000 feet
Speed:	150-330 knots True Air Speed
Payload:	20,000 lb

Accommodations

Zenith and Nadir Viewports
External Antenna Attachment Mounts
Optical Windows
19-inch Panel Equipment Racks

Support

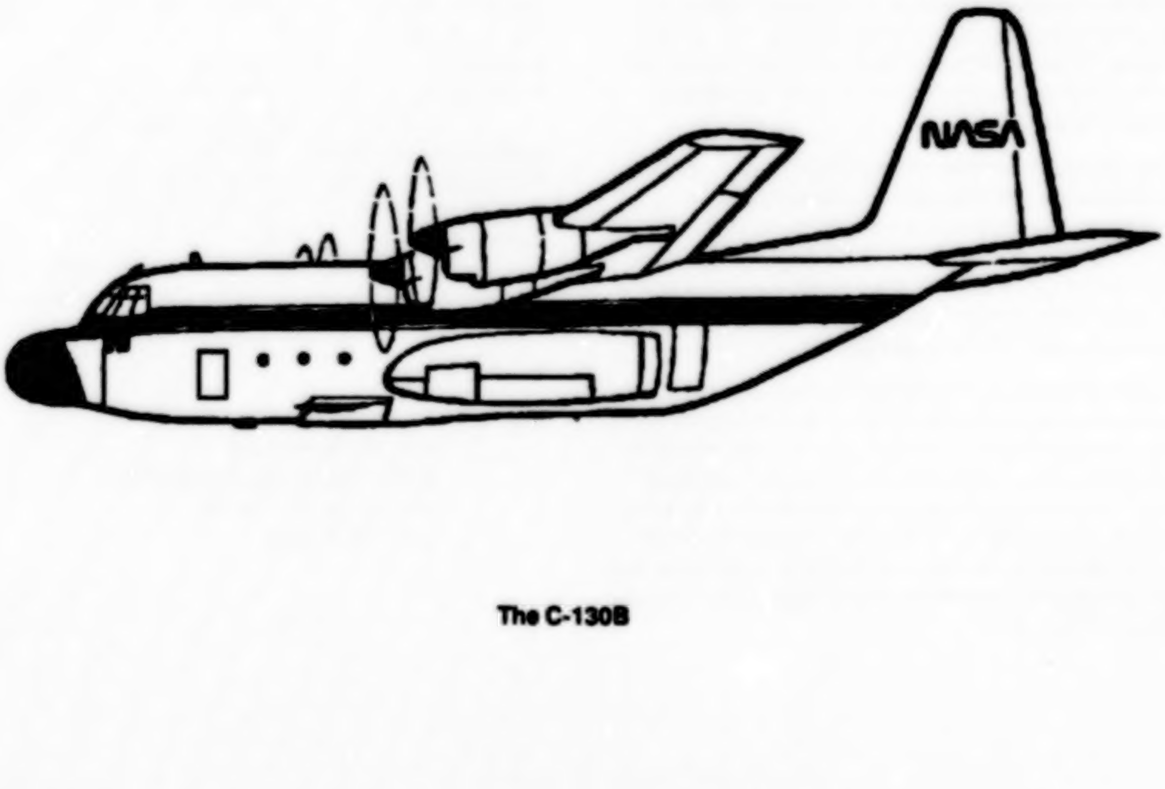
Navigation Flight and Environmental Data Recorded Automatically and Available to Investigator
Dew/Frost Point Hygrometer
Radar Altimeter
Weather Radar
Inertial Navigation
Time Code Generator
Housekeeping Distribution

Sensors

Metric Cameras
Multispectral Scanner
Walk-on: Eight Stations Provided for Investigator Supplied and Operated Sensors

Available: Now

Contact: Bruce Coffland
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffet Field, CA 94035-1000
(415) 604-6252



The C-130B

ER-2, Lockheed

There are three ER-2 aircraft available at the NASA/Ames Aircraft Data Facility. These high-altitude aircraft, or instrument platforms, accommodate an extensive group of sensors used for upper atmospheric measurements. The ER-2 also accommodate a complement of sensors maintained by Ames Research Center for observations of the Earth's surface. The high altitude missions involve collection of data in three principal areas: atmospheric data within the stratosphere, Earth and celestial observations using electronic sensors and photographic data acquisition.

Performance

Altitude:	70,000 feet (max)
Range:	3,000 nautical miles
Duration:	8 hours (Nominal 6.5 hours)
Speed:	410 knots True Air Speed
Payload:	600 lb, Nose; 750 lb, Q-bay; 1,360 lb, Wing pods

Accommodations

Q-Bay Instrumentations Area and Payload Pallets (Pressurized) Wing Mounted Instrumentation Pods (Pressurized)
Nose Cone Instrumentation Area (Pressurized)
Zenith and Nadir Viewing Capability

Support

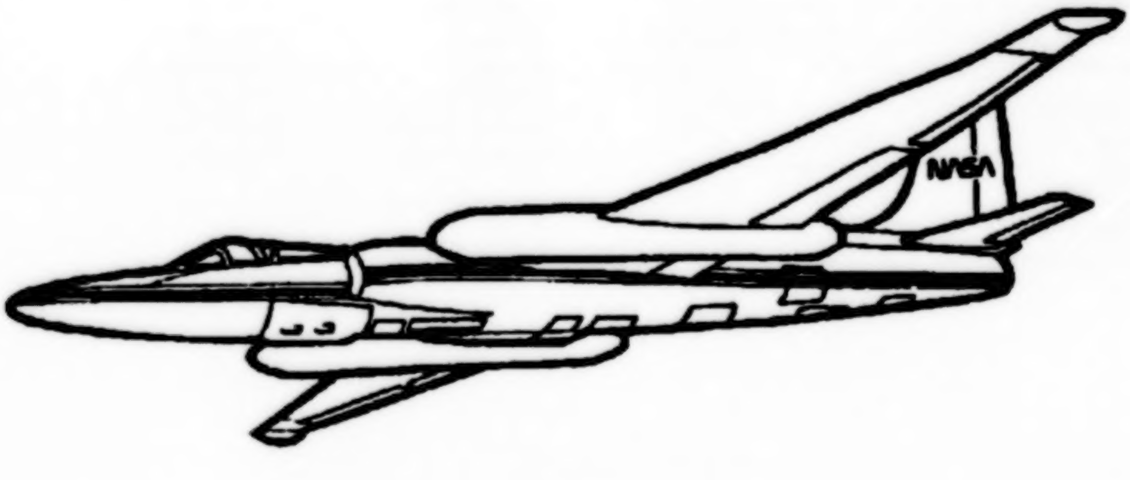
Inertial Navigation
Satellite NBS Time Code Receiver
Navigation Data Recording System

Sensors

High Altitude Multispectral Scanner
Thematic Mapper Simulator (TMS)
Airborne Ocean Color Scanner (AOCI)
Multispectral Atmospheric Mapping Sensor (MAMS)
JPL Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
Electro-Optical Camera
High-Resolution Panoramic Cameras

Available: Now

Contact: Bruce Coffland
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffet Field, CA, 94035-1000
(415) 604-6252



The ER-2

Electra L-188, Lockheed

The Electra supports a major atmospheric science program for NASA called the Global Tropospheric Experiment (GTE).

Operational Characteristics

Altitude:	25,000 ft
Range:	2,000 miles
Endurance:	7.5 hours
Payload weight:	19,000 lbs
Payload power:	40.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804)824-1448

Gates Learjet, Model 23-049

The Stennis Space Center operates a Learjet in support of NASA's Earth Sciences Program. The Learjet flies two instruments: the Calibrated Airborne Multispectral Scanner (CAMS), used to study coastal geomorphology and evapotranspiration, and the Thermal Infrared Multispectral Scanner (TIMS), used for geology studies and land cover classification.

Operational Characteristics

Altitude:	41,000 ft
Range:	1,000 miles
Endurance:	3.0 hours
Payload weight:	750 lbs
Payload power:	4.0 kW

Available: Now

Contact: Patrick Kelly
NASA/Stennis Space Center
Stennis Space Center, MS 39529
(601) 688-1919

Lockheed P-3A and P-3B

The P-3 supports regional and local studies and instrument development work. The P-3B provides enhanced range and endurance.

P-3A Orion

Altitude:	25,000 ft
Range:	2,000 miles
Endurance:	7.5 hours
Payload weight:	13,600 lbs
Payload power:	33.0 kW

P-3B Orion

Altitude:	28,000 ft
Range:	3,000 miles
Endurance:	12.0 hours
Payload weight:	13,600 lbs
Payload power:	33.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804) 824-1448

Rockwell T-39 Sabreliner

The Sabreliner provides the capability of reaching altitudes nearer to the stratosphere. The aircraft is being modified with an upward-looking window for atmospheric research.

Operational Characteristics

Altitude:	41,000 ft
Range:	1,400 miles
Endurance:	3.25 hours
Payload weight:	1,500 lbs
Payload power:	3.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1448

Short Brothers SC-7 Skyvan

The Skyvan's primary role involves mid air retrieval of rocket-launched payloads. However, the aircraft also is used to support Earth resources studies and instrument development work.

Operational Characteristics

Altitude:	15,000 ft
Range:	650 miles
Endurance:	4.0 hours
Payload weight:	5,000 lbs
Payload power:	2.8 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1448

Bell UH-1B Helicopter

This helicopter is used as an instrument platform for Earth resources work.

Operational Characteristics

Altitude:	10,000 ft
Payload weight:	2,000 lbs
Payload power:	3.5 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804) 824-1448

Section Three: Hardware & Equipment

Flight-qualified experiment apparatus, support hardware and payload services are available to commercial researchers for use in materials processing, life sciences and biotechnology, remote sensing, automation and robotics, combustion engineering and other disciplines.

This equipment is used for ground-based testing, such as in labs or drop towers; in the air, on balloons or aircraft; or in space, on the Shuttle, expendable launch vehicles or on-orbit facilities. Some of the entries on the following pages can be accessed through NASA, while others are offered commercially. Some have been designed, flight-tested and are available; others are conceptual designs or prototype hardware. These indications are noted for each entry. Note that all equipment must satisfy the safety or integration requirements of the applicable carriers. The equipment is subject to manifesting or scheduling constraints and the integration lead times of those carriers.

The chapters in this section are assigned to Microgravity Research; Remote Sensing; and Support Products and Services.

Chapter 8: Microgravity Research

Microgravity is a state in which the force of gravity experienced is significantly less than that on the surface of the Earth. Process variables behave differently in microgravity: buoyancy-driven forces such as sedimentation and convection can be virtually eliminated. Weak surface forces, otherwise suppressed by gravity, are exaggerated. The prospect of an environment in which these variables can be controlled has attracted the interest of researchers in such fields as biotechnology, electronics, glass and ceramics, polymers, and metals and alloys.

Microgravity research already has led to significant advances in materials science, to improved ground-based production methods and to other industrial applications. The field holds potential in numerous areas, such as pharmaceuticals, semiconductors, new alloys, materials separation and composites, and containerless processing. Continued research is expected to lead to commercially viable products, uniquely suited to space-based production; it may be possible to produce materials in space that cannot physically or cost-effectively be produced on Earth. The knowledge pool is just beginning to accumulate.

The most sophisticated microgravity research facility is the Shuttle. While microgravity experiments are limited to periods of a few seconds in a sounding rocket, aircraft or ground-based drop tube, they are conducted for a few hours or days aboard the Shuttle, with or without the hands-on attention of crew members. The development of new on-orbit platforms and, particularly, recoverable payload systems is expanding the researcher's opportunities. Sponsorship for a flight program may be obtained in several ways. NASA itself sponsors many projects, as do other agencies, universities, industries and foreign governments. (See Scheduling, Chapter 3.)

The equipment described in this chapter supports ground-based, airborne and spaceborne research for materials processing (beginning on page 66), life sciences and biotechnology (both beginning on page 93). Microgravity research is a relatively new space science that demands rigorous preparation and planning. Because gravity is a dominating force on Earth, designing experiments to operate in the near absence of gravity is a challenge. Any researcher planning to experiment in the microgravity environment should consider the possibility and benefits of using existing equipment.

Materials Processing

A major emphasis of commercial research in microgravity has been in the area of materials processing. Microgravity offers an ideal environment for containerless processing, which may result in the production of materials with unique properties. The field of processing within a container in a microgravity environment also shows potential because in space there is no natural convection as there is on Earth. A result of this characteristic is the production of composite materials which are much more uniform in composition and microstructure.

Emphasis in metals research includes single-crystal alloys, intermetallic compounds, refractory metals and composite materials for use in engine components. Polymer matrix composites are being investigated for potential use in motors, structures and other applications. Ceramic research is seeking to better understand and control the microstructure/property relations in high-temperature structural ceramic systems. Ceramic and metallic coatings are being developed to provide protection for components in high-temperature, corrosive/erosive environments. Tribological experiments will yield a better understanding of the behavior of interfaces (e.g. solid-to-solid contact) in mechanical systems such as engines, components and mechanisms.

All of these research activities are supported by facilities and laboratories which provide analysis and documentation of the chemical composition and microstructure of advanced materials, metals and nonmetals. They also are supported by the experiment equipment and hardware that is designed for efficiency, survivability and productivity.

Furnaces

Advanced Automated Directional Solidification Furnace (AADSF)

The advanced design of the AADSF for improved temperature control between the hot and cold ends of the sample allows a nearly planar interface to be maintained between the melt and solid states of a sample alloy. This expands the capabilities of studies that examine gravity limits and how convection influences the homogeneity and defects of a crystal.

The apparatus contains a multi-zone furnace and a mechanism that moves the sample through the furnace. The furnace may be configured to compensate for changes in temperature as a sample adjusts to its steady-state value, changes in thermal conductivity between solid and melt and energy disposition. One sample per furnace of approximately 1.5 cm diameter by 25 cm in length is planned.

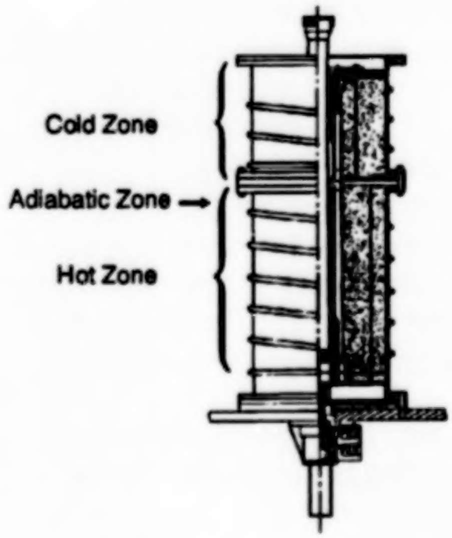
Operational Characteristics

Temperature range:	200° to 1600° C
Translation rate:	0.5 to 50.0 mm/hour
Furnace size:	130 cm H x 43 cm diameter
Furnace weight:	120 kg

Carrier: Materials Science Laboratory (MSL)

Available: Engineering prototype completed.

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



ATAKSAK-1, Atmosphere Furnace

ATAKSAK-1 is a high-temperature controlled atmosphere furnace designed to rapidly heat materials to high temperatures (above 1800° C). Current system configuration (designed for sounding rocket flights) allows the furnace chamber (2 inch diameter x 4 inches deep) to be heated to a moderate temperature (approx. 1300° C) using 1 kW of off-board AC power. During flight, the furnace is energized using on-board batteries. The temperature can be pulsed to above 1800° C in less than one minute. The present controller design allows the soak temperature to be maintained for up to 7 minutes.

As configured, the furnace is suited for the synthesis of materials at high temperature, for the production of microcrystalline materials at the laboratory scale and in situations where available power is limited. Depending on the particular application, the configuration can be extended to include other features such as longer soak time, programmable ramps, atmosphere control and larger furnace chambers.

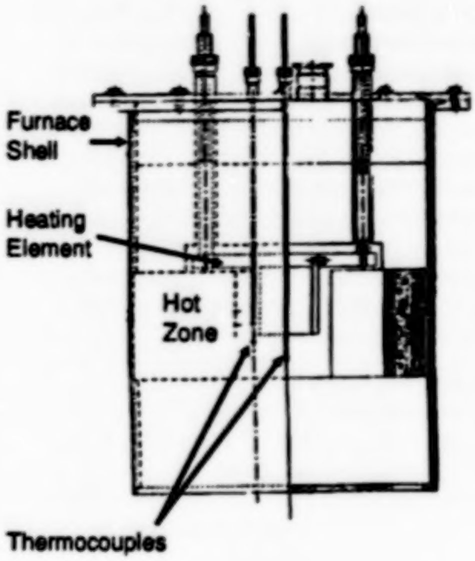
Operational Characteristics

Furnace chamber:	4 in L x 2 in diameter
Furnace shell:	15 in L x 14.5 in diameter
Controller:	12 in x 12 in x 8 in
Furnace mass:	24 lb
Controller mass:	10 lb

Power: 1 kW to 1300° C, 1-9 kW to >1800° C
Pulse time, 1300° C to 1800° C: <1 min on battery operation

Available: Available for ground-based testing and configured for sounding rocket flight.

Contact: A. Pant or C. Bell
Ceramics Kingston Inc.
P.O. Box 655
Kingston, Ontario, K7L 4X1, Canada
(613) 548-7253, Fax (613) 542-2856



Bulk Undercooling Furnace

The Bulk Undercooling Furnace (BUF) is a three-zone furnace designed to study the effects of undercooling on the microstructure of metal alloys. The temperature is sampled using a thermocouple and controlled using a small computer.

Operational Characteristics

Operating Temperature:	25° to 500° C
Max. Power/zone:	300 W
Cooling fluids:	Argon, helium, nitrogen, air, water
Sample Shape:	Cylindrical
Sample Length:	12 cm maximum
Max Diameter:	3.5 cm

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory (MMSL)

Available: Now

Contact: T. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road, MS 105-1
Cleveland, Ohio 44132

Crystals-By-Vapor Transport (CVT) Furnace

Each Crystals-By-Vapor Transport Furnace is used to grow up to two samples simultaneously. A two-zone heater coil for each sample is used to establish and control a temperature gradient for the desired growth conditions of each particular material. The diameter and pitch of the coil may be modified to accommodate the desired temperature profiles of a wide range of materials.

Current furnace system configurations allow for visual observation and man-in-the-loop control of the growth nucleation and processing. This viewing feature is achieved with the use of a gold-coated quartz tube, which reflects heat but is transparent to visible light and viewports in the outer containment shell. The system provides for the majority of the processing to be automated. This is achieved with the use of a stepper motor drive which provides quasi-continuous pulling of the ampoule in 3 micron increments. Approximately 5 grams of source material can be processed in a two-walled ampoule with an inner diameter of up to 25 mm.

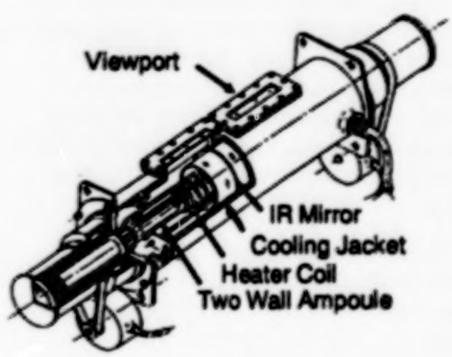
Operational Characteristics

Operating temperature:	Up to 900° C
Furnace size:	7 in x 7 in x 40 in (holds 2 samples)
3-Furnace system size:	20 in x 70 in x 16 in (fits in single standard rack)
Weight:	490 lbs
Power requirement:	Up to 1 kW (for current systems)

Carrier: Shuttle-middeck accommodation rack

Available: Presently available for the Shuttle middeck. Minor modifications are needed for use in the Shuttle cargo bay and for the Freeflyer/Space Station.

Contact: V. A. Swebert or D. M. Garman,
Boeing Commercial Space
Development Company
P.O. Box 3707, M/S 8C-64
Seattle, WA 98124
(206) 773-5176



Crystal Growth Apparatus (CyGA-400)

The CyGA-400 is a low cost, low weight, modular device designed for growing crystals of proteins, drugs and other organic and inorganic materials in the microgravity environment of Low Earth Orbit. This device can be used in conjunction with the COR Aerospace re-entry recovery vehicles and MaRP* Process for protecting the crystals until they are harvested for analysis in ground-based laboratories.

This device can hold up to 400 individual samples with easy access of solution and removal of crystals. The unit is modular, such that a different number of units may be assembled, providing a high volume of individual crystal growth chambers in a compact space. The maximum number of units utilized depends on the size of the re-entry recovery vehicle. For example, the Deliver-24* vehicle can accommodate up to nine CyGA-400* modules giving a total of 3600 individual crystal growth chambers and (using the COR Aerospace temperature control and MaRP devices) still leaving up to one cubic foot of payload volume for other experiments. The CyGA modules can be custom-tailored with a different number of individual crystal growth chambers from 100 (CyGA-100) to 1000 (CyGA-1000) per module, depending upon user needs.

**CyGA-"X", Deliverer-24, and MaRP are trademarks of COR Aerospace Corporation*

Operational Characteristics

Size of Unit:	10 cm x 10 cm x 10 cm
No. of Samples:	Up to 400
Sample Volume:	Range of 50 to 500 microliters
Temperature:	4° to 50° C with +/-0.3° C control

Available: Now

Contact: COR Aerospace Corporation
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 676-2474

Electromagnetic Levitation/Float Zone Furnace (EML/EFZ)

This facility uses an induction furnace in two modes. As a levitation furnace, it levitates and melts small metal alloy samples. As a float zone furnace, it can process small diameter metallic sample rods. In both modes the furnace can maintain vacuum or an inert gas atmosphere.

Operational Characteristics

Power:	0 to 25 kW
Frequency:	100 to 450 kHz
Vacuum:	to 10^{-6} torr
Inert gases:	Argon, helium

Sample Shape

EML:	Spherical or cylindrical (height=diameter)
EFZ:	Rod

Sample Size

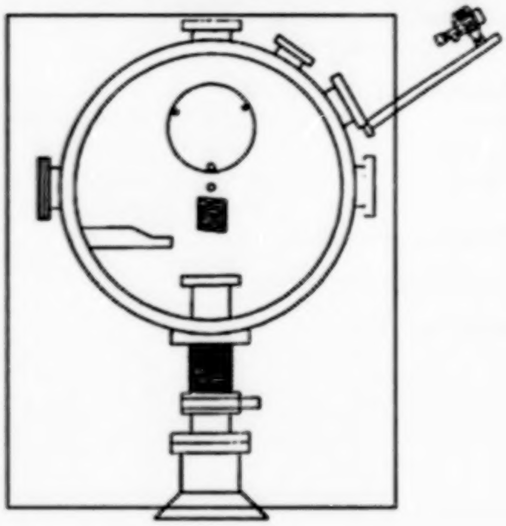
EML:	0.5 to 4 cm^3, up to 30 g
EFZ:	approx. 5 mm diameter

Sample Type: Any material that can be levitated and/or heated inductively

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory

Available: Now

Contact: T. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road, MS 105-1
Cleveland, Ohio 44132



Electromagnetic Levitation Furnace

The Electromagnetic Levitation Furnace is used in a containerless process to melt metallic samples of up to about one gram. The device allows the investigation of various physical phenomena including vacuum purification, undercooling, solidification kinetics, rapid solidification and the formation of metastable phases. Significant stirring occurs in the samples due to the RF-induced eddy currents. The samples can be cooled at a controlled rate by blowing helium gas over them after which splat quenching is possible with a light, trigger-activated, double anvil splat quencher. The temperature of the sample can be monitored with a two-color pyrometer. Samples can be processed in a vacuum of 2 x 10^{-5} torr or various gases up to 1 atm.

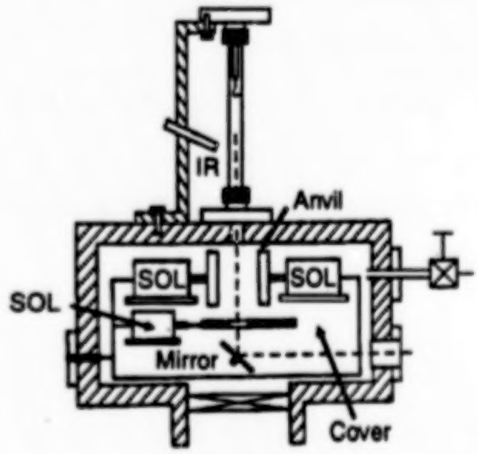
Operational Characteristics

Sample sizes:	Approximately 1 gram
Vacuum level:	2 x 10^{-5} torr
Controlled cooling:	Yes
Splat quenching:	Yes

Carrier: Designed for ground-based research only

Available: Now

Contact: Center for Space Processing of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7053



Flat Plate Heater

The Flat Plate Heater is used to heat a flat sample 114 mm x 114 mm square. Variable thicknesses of samples are accommodated. The heater operates by a single set point controller. Heat-up rate depends on the power supplied to the heater pads which are on both sides of a sample. Maximum operating temperature is 200° C. Heat-up time to 200° C is approximately two minutes. The device can be used to cure epoxy resins.

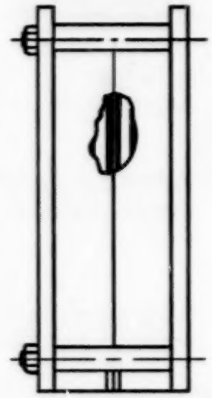
Operational Characteristics

Size:	153 mm x 163 mm x 80 mm
Weight:	1.6 kg
Power:	2 heaters, requiring approx. 6 amps each at 28 Vdc
Operating temperature:	200° C

Carrier: Sounding rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620



Gradient Furnace for the Get-Away-Special Canister (GFGAS)

The GFGAS was developed to provide a low-cost, quick turn-around furnace for fundamental studies of transport phenomena in crystal growth processes. The furnace recrystallizes a previously grown gallium arsenide (GaAs) crystal by thermal gradient transport. High-quality GaAs crystals may prove to be the basis for a new high-speed semiconductor technology.

In each of two furnaces, an Earth-grown GaAs seed crystal is melted back to 2.54 cm, then regrown to 7.62 cm. The recrystallization is accomplished by passing a thermal gradient along the length of the sample, resolidifying the crystal. Sample size is 22 mm diameter by 10 cm in length.

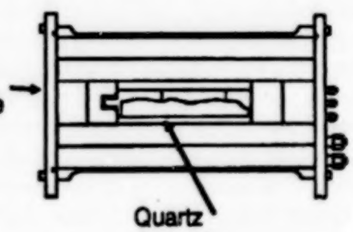
Operational Characteristics

Temperature:	1,330° C maximum
Furnace size:	60.96 cm H x 50.16 cm diameter
Furnace weight:	90 kg

Carrier: GAS canister for use in Shuttle cargo bay

Available: Now

Contact: Richard W. Lauver
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2860



Ground-Based Acoustic Levitator (Beam Heated)

This facility is a high-temperature acoustic levitator for precursor experiments in low gravity. It can be flown aboard the KC-135 aircraft and the design could be adapted to a sounding rocket carrier. Beam heating by xenon arc or laser will provide rapid sample heating to temperatures exceeding 2000° C, depending on sample characteristics. Sample sizes ranging from 2-6 mm can be accommodated. Control of sample rotation and oscillation is possible. The samples may be processed in various inert or reactive environments.

Video and thermal imaging is available in orthogonal directions. Thermal imaging at several different optical wavelengths provides the user with non-contact temperature measurement capabilities.

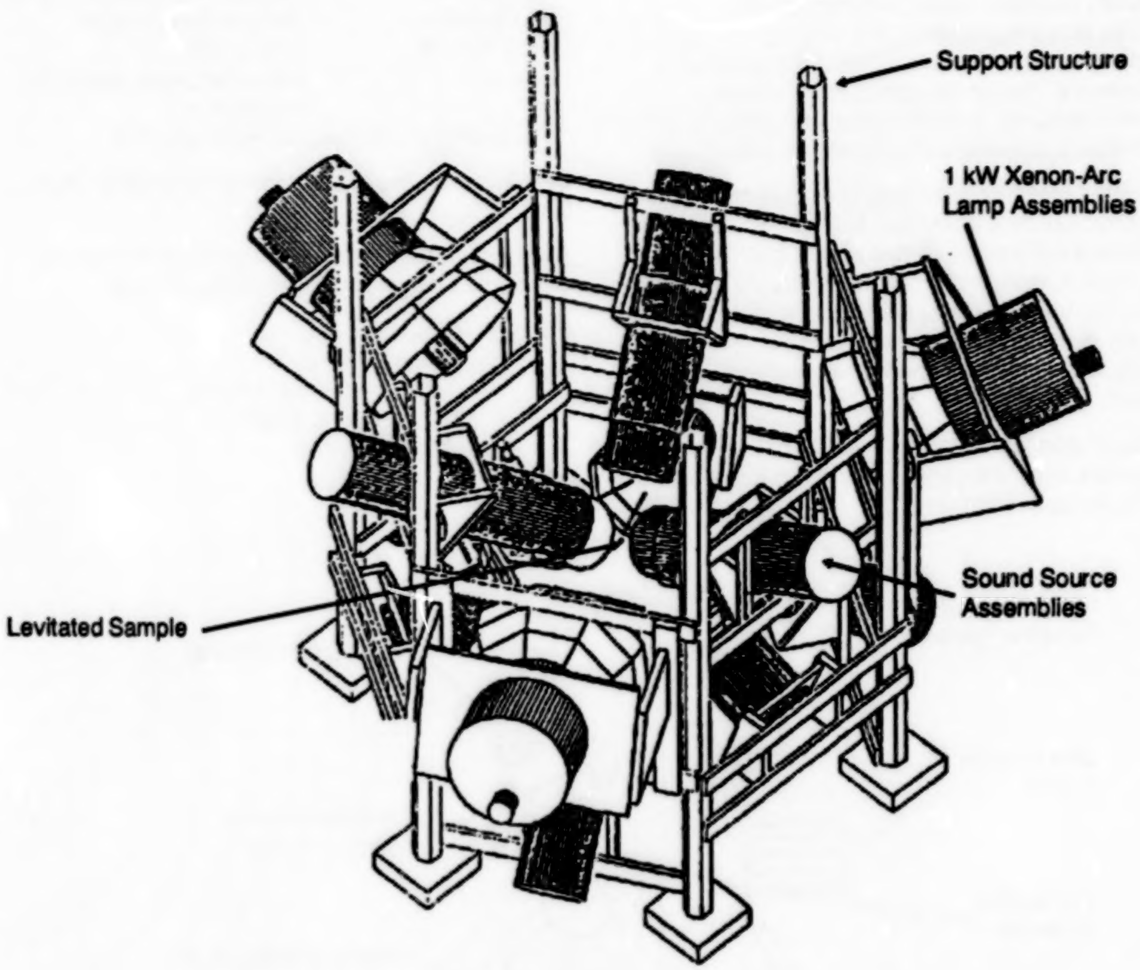
Operational Characteristics

Temperature for sample heating:	2000°+ C
Sample size:	2 to 6 mm

Carrier: KC-135 and sounding rockets

Available: A breadboard version of this facility has been developed at Intersonics, Inc. and tested in a laboratory and on the KC-135 aircraft.

Contact: Dennis Merkley
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Test Facility Aboard KC-135

High Temperature Acoustic Levitator (HAL)

The High Temperature Acoustic Levitator (HAL) is a containerless processing module which uses a 3-axis acoustic positioning system in order to contain non-conducting as well as conducting liquid and solid materials. This acoustic positioning system has the capabilities for providing accurate specimen positioning and for producing a quiescent, spin-free and stable specimen state.

HAL uses xenon arc or laser beam heating for high-temperature containerless testing and processing studies of glass, ceramic, metal and alloy samples in microgravity. It has capabilities of processing, heating, melting, soaking, cooling and solidifying samples without the physical contact of a container. Advantages of this system include extremely stable sample positioning utilizing optical feedback, and fast heating and cooling rates. Samples may be processed in a very high purity, particle free, inert, oxidizing or reducing gaseous environment. The device can accept nominally spherical samples, 2-6 mm in diameter, and can perform a large number of experiments sequentially.

The sound pressure level is electronically monitored and controlled by a computer. This can be used to modulate the shape of a liquid sample in order to study fluid dynamics of drops or to measure physical properties, such as surface tension and viscosity. By properly phasing the acoustic signals between transducers, controlled spin of the specimen can be attained.

The open architecture of the levitator allows convenient access for both invasive and non-invasive diagnostic equipment.

Operational Characteristics

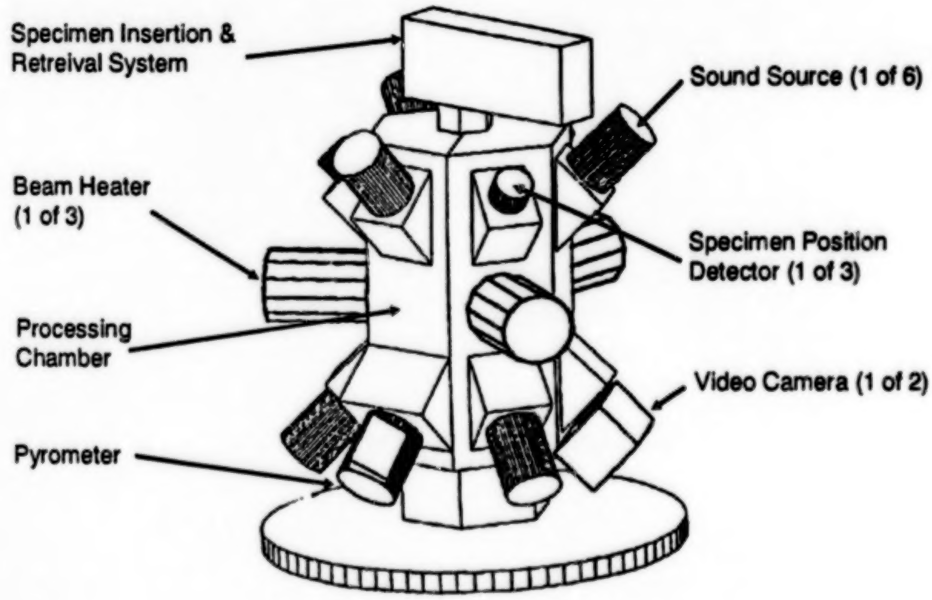
Temperatures*:	30° to 2,000° C
Design Goal:	up to >2700° C
Isothermality*:	Good
Temperature Control	
Precision:	To be determined
Design Goal:	1° C
Gas Purity and Particulate Contamination:	Excellent (as good as process gas)
Process Gas:	Oxidizing, reducing or inert
Specimen Motion:	<1 mm (electronically controlled)
Specimen Density:	0 to 22 gm/cm^3
Position Accuracy:	<+/-1 mm
Heating Rates*:	0 to 200° C/second or higher
Cooling Rates*:	0 to 200° C/second or higher
Spin Control:	Zero, or very low spin
Optical Access:	Convenient
Heaters:	Xenon arc, laser beam, RF, microwave

** Dependent on sample properties and size*

Carrier: Sounding rocket, freeflyer or Shuttle cargo bay

Available: Design has been developed through the breadboard stage and tested on the KC-135

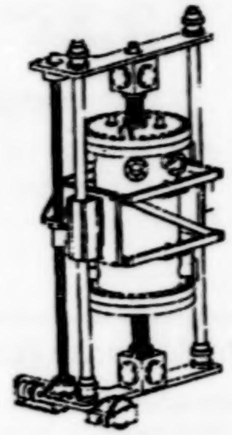
Contact: Charles A. Rey
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Module

High Temperature Directional Solidification Furnace

The High Temperature Directional Solidification Furnace allows directional solidification experiments on materials with melting temperatures over 2,000° C. Dual water-cooled copper blocks with helium gas convective cooling provides thermal gradients in excess of 200° C/cm. The superior electrical, magnetic or mechanical properties of high melting point samples with unique, directionally solidified structures can be investigated with this apparatus.



Operational Characteristics

Temperature:	1,000° to 2,500° C
Translation speed:	0.01 to 30 mm/minute
Fast quench:	30 mm/second
Sample size:	20 cm L x 1.2 cm diameter

Carrier: Designed for ground-based research only

Available: Now

Contact: Center for Space Processing
of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7054

High Temperature Directional Solidification Furnace

The High Temperature Directional Solidification Furnace is designed to perform directional solidification experiments on metal samples at much higher temperatures than those used in the Transparent Directional Solidification Furnace. The sample is sealed in a quartz ampoule and the furnace heating coil assembly is moved along the length of the tube. The sample is exposed to a large magnetic field to reduce convective flow.

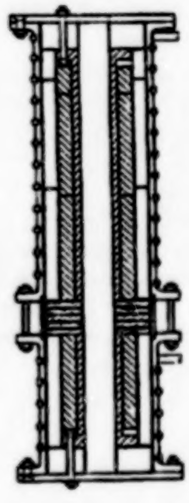
Operational Characteristics

Oven temperature:	Air 200° to 1100° C, Inert atmosphere 200° to 1400° C
Hot zone length:	20.32 cm
Cold zone length:	10.16 cm
Quench zone length:	10.16 cm
Translation rate:	25.4 to 0.10 cm/second
Temperature gradient:	10,200 and 400° C/cm
Sample shape:	Cylindrical
Sample diameter:	12.7 or 28 mm
Sample length:	20 cm to 26 cm
Ampoule length:	Approximately 100 cm

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory

Available: Now

Contact: Mary Jo Meyer
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-8165



Isothermal Casting Furnace

This high-temperature furnace has a helium quench gas to resolidify the sample during flight.

Operational Characteristics

Operating temperature:	200° to 1350° C
Cooling rate:	1° to 50° C/second
Power:	7.0 amps
Voltage:	28 Vdc
Size:	61 cm L x 43 cm H x 31 cm diameter
Mass:	24 kg
Sample size:	2.0 cm L x 1.0 cm diameter maximum

Carrier: Designed to fly on TF-104G research aircraft. May be modified to fly on KC-135 if necessary.

Available: Now

Contact: I. C. Yates
NASA/Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
(205) 544-1997

Isothermal Multipurpose Furnace Modules (TEM 01)

This module contains either four or six heating chambers that can be controlled independently of each other and have separate cooling systems that operate independently. The module can be used to implement any kind of melting experiment which requires isothermal conditions. The furnaces are sealed and can be filled with any inert gas atmosphere. The furnaces are activated during the countdown phase until the proper temperature is attained.

Applications include melting experiments with alloys, dispersion alloys, skin technology, glass experiments, metal foams, directional solidification, eutectics, crystal experiments and soldering experiments.

Operational Characteristics

Type of furnace:	PtRhPt heater
Maximum temperature of heater:	1600° C
Diameter of heater:	15 mm to 20 mm usable for sample
Heated length of heater:	65 mm
Isothermal zone:	22 mm
Isothermal condition:	+/-5° C depending on sample
Gradient:	10° to 40° C/cm depending on sample
Number of temperature measurements:	2 to 4
Type of thermocouples:	NiCrNi, PtRhPt
Cooling system:	Helium gas (during the microgravity phase)
Cooling rate:	100-300° C/minute
Heating rate:	6° C/second maximum
Programming:	Independently

Power System

Electronic:	NiCad 28 Vdc/2.5 Ah
Furnaces:	28-35 Ag/Zn SHV 500 cells 1.2 V/cell for each furnace
Maximum current:	30 A (for a short time)

PCM-System

Data transmission:	Real-time
Resolution:	0 to 5 V, 10 bit 0/1 event status
Number of analog channels:	64
Number of digital channels:	60

Sample

Length:	50 mm maximum
Diameter:	12 mm to 18 mm maximum
Temperature:	1500° C maximum

Carrier: Sounding rockets

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Mirror Furnace Modules (TEM 02)

The TEM 02 experiment module is equipped with a rotationally symmetric ellipsoid mirror furnace. The sample, sealed in a 20-mm quartz ampule, is located at the first focus of the ellipsoid and is heated, without contact, by a lamp at the second focus of the ellipsoid. The maximum sample length is 90-mm. The sample may be observed during flight by a B/W or color TV and may be photographed by a remotely operated camera. The module provides the capability for in-flight telecommand control of the furnace (12 channels) and accommodates three different modes.

Applications include crystal growth, eutectics, directional solidification, acoustic positioning and electrostatic positioning.

Module TEM 02-2
This module is a mirror furnace that can be equipped with a 450 to 1000 W lamp for pure melting experiments. It can be utilized in connection with an ultrasonic positioner or an electrostatic positioner.

Module TEM 02-3
This module is used for crystal growth experiments. In addition to the mirror furnace, it has two motor systems needed for sample rotation and sample translation.

Module TEM 02-4
This module is almost identical to the TEM 02-3 module, but contains only one motor for sample translation. This module is used for crystal growth experiments as well as for directional solidification experiments. It is possible to integrate a cooling device to the bottom of the sample.

Mirror Furnace
The mirror furnace is a monoellipsoid type: a halogen lamp is located in the first focus and the sample is located in the second focus. Melting of the sample is performed by drawing it through the illumination zone of the focus. The ellipsoid can be filled with different gases, depending on the sample requirements.

Lamps/Temperatures
Halogen lamps, used for the melting process, operate at temperatures of up to 3300° C. The highest temperature used in the mirror furnace to date has been 1500° C.

Sample Movement and Positioner System
Two independently controlled motors with tachometer generators are installed to translate and to rotate the sample holder. Adjustments are possible within the following ranges:

- Translation: 1 to 10 mm/min
- Rotation: 1 to 10 rpm/min

In order to perform a containerless melting process, the motor system can be replaced by:

- Ultrasound positioner system, or
- Electrostatic positioner system

Power System

Electronic:	NiCad 28 Vdc/2.5 Ah
Lamp power:	SHV 500 Ag/Zn cells, 1.2 V/cell, 450 W lamp 40 cells 1000 W lamp 120 cells
PCM-System:	32 analog channels, 0 to 5V, 10 bit 30 digital channels, 0/1 event status
Timer:	1 x 16 independent events extension to 2 x 16 events is possible
External/Internal:	1 unit for electronic power
Switch:	1 unit for lamp power

Carrier: Sounding rockets

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Module (TEM 03)

The module TEM 03 is a gradient furnace with two independently controlled heaters within the furnace. The gradient for the sample is achieved in a baffle zone between the heaters by moving the furnace slowly over the sample. The highest temperature of the sample may be up to 1200° C and the established gradient, in the order of 20 to 120°/cm. The established gradient and temperature are very strong and depend on the sample size and material properties of the sample and cartridge. Therefore, the given data have to be considered as preliminary. The arrangement of heaters and baffle has to be adapted, depending on experiment requirements, and verified by a number of ground tests, before the flight unit is well adjusted concerning heater, sample size and translation velocity. The data given below are generated for tests with a GeGa test sample.

Planned module length:	1,000 mm
Planned module weight:	72 kg

Furnace

Diameter:	330 mm
Length:	680 mm
Heater:	Two heaters made from PtRhPt
Heater 1:	145 mm length
Heater 2:	70 mm length
Temp. Heater 1:	1300° C
Temp. Heater 2:	700° C

A gas or water system can be adapted to the lower heater (#2).

The baffle zone, being the insulation zone between the two heaters, measures about 20 mm. Within this baffle zone, a very flat solidification front can be established.

Furnace Velocity: Adjustable range of 0.1 mm/min to 10 mm/min

Power Supply

Electronic:	NiCad 28 Vdc/2.5 Ah
Furnace:	Ag/Zn SHV500 1.2 V/cell

Number of cells to be determined by required temperature/time profile.

Sample/Cartridge

The sample consists of a cartridge and the sample material itself.

Cartridge:	Length: 300 mm
	Diameter: 13 mm
Material:	Tatalium
Sample:	Length: 100 mm
	Diameter: 10 mm
	Material: GeGa

The drawing length of the sample during the process is 70 mm. The TEM 03 furnace positions only the drawing process in microgravity, because it uses material already melted before on the ground.

Temperature Measurement

Heater temperature control is performed by one NiCuNi element per heater. Gradient measurement within baffle zone is done by 2 NiCuNi elements, designed as slide contact elements, and measures temperature on the surface of the cartridge motor system.

Pulse Marker

A pulse marker can be adapted to the sample material in order to measure the fluid/solid interface during the drawing process.

Pulse

Amplitude:	50A DC
Duration:	Maximum 100 μs
Sequence:	Adjustable

Carrier: Sounding rockets

Available: This module is in the development phase and planned for the TEXUS 27/28 flight. Final technical descriptions will be made available in 1991.

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Multi-Mission Mirror Furnace Module (M4)

The furnace is designed for short-duration microgravity applications in sounding rockets, making it necessary to have a very rapid furnace, both in heating up and cooling down performances. Therefore, a mirror furnace concept with as low thermal mass as possible was chosen.

This module contains two advanced isothermal mirror furnaces, standing along the center axis. In the lower end of the cylinder is an aluminum panel on which the furnaces rest. On the other side of the panel the power transistors are maintained, using the panel as a heat-sink. On the walls of the outer structure, the four (or two) gas vessels for quenching the samples are mounted. The furnace computers and control electronics are mounted on two lids in the structure, and between the gas vessels is mounted a box containing batteries for electronics and a box for housekeeping functions of the module.

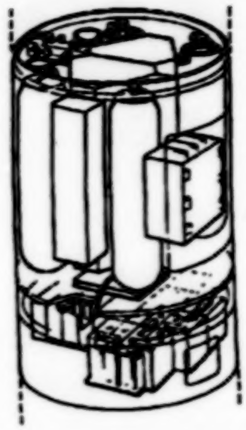
Operational Characteristics

Size:	765 mm L x 438 mm diameter
Weight:	75.5 kg including battery module and 2 gas vessels
Material:	Outer structure is magnesium casting; inner structure is aluminum panel
G-forces:	Approx. 14 g maximum
Number of furnaces:	2
Sample size:	160 mm L x 15 mm diameter
Operation temperature:	50° to 1,000° C
Isothermal properties:	+/-0.5° C along the whole sample length

Carrier: Sounding rockets

Available: Now

Contact: CONATEC, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088



Multi-Zone Furnace

This multi-zone furnace (24-independent zones) originally was designed for directional solidification crystal growth. The furnace, tubular in shape, is translated around the sample. State-of-the-art computer-controlled operations allow adjustments of the temperature profile to vary throughout the sample and to be programmed over time. Thermocouples throughout the system allow the temperature versus time and versus location to be displayed as programmed. The flexibility of the system is such that this furnace is ideal not only for directional solidification, but also for other methods of crystal growth, such as vapor transport and gradient freeze.

Operational Characteristics

Operating temperature:	Up to 1,600° C with control stability to +/-0.2° C
Furnace size:	60 in L x 20 in W x 2 1/2 in bore
Furnace system size:	Semicylinder, 8 ft L and 36 in diameter
Weight of system:	<2000 lb
Power:	<1.75 kW

Carrier: Originally designed for mounting on an across-the-bay structure such as the Microgravity Material Science Laboratory carrier. Redesigned to be mounted on 2 Get-Away Special beams on the Shuttle side wall. Could be adapted to middeck (major modification).

Available: Tested on a ground system which was designed for flight requirement. A specific flight configuration would need modifications.

Contact: Joseph Alario
Grumman Space Systems Division
A05-025, Grumman Corporation
Bethpage, NY 11714
(516) 575-2433

Physical Vapor Transport Crystal Growth Furnace

The Physical Vapor Transport Crystal Growth Furnace is a transparent multi-zone furnace. It has a sample translation system designed to provide slow movement of the sample between the heating coils. The sample is sealed into a quartz ampoule and attached at the top to a guide wire connected to the sample translation device. The guide wire is used to move the sample between the two heated areas of the furnace very slowly. Crystals are grown in the upper end of the furnace as the vapor produced by the material under study contacts the glass.

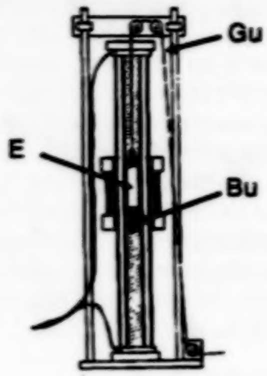
Operational Characteristics

Growth rates:	50 nm/sec to 50 microm/sec
Thermal gradient:	20° C/cm
Maximum furnace temperature:	600° C
Sample shape:	Cylindrical
Mass:	100 g

Carrier: Designed for ground-based research only (MMSL)

Available: Now

Contact: Bruce Rosenthal
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5027



Sheet Float Zone Furnace (SFZF)

The Sheet Float Zone Furnace (SFZF) is a materials processing furnace specifically designed and built to make use of the 20 to 25 seconds of low gravity provided by parabolic flight aircraft (such as the KC-135). The SFZF uses a unique sample format and heater arrangement providing the capability to melt and resolidify bulk quantities of material during this short low gravity period. The resulting resolidification is both directional and containerless.

The SFZF uses movable focusing infrared line heaters to apply heat to a narrow band along a sample. A typical sample is preheated by scrolling the heater back-and-forth during the interval between low gravity periods to bring it to near its melting temperature. As low gravity conditions begin, the heaters are brought together, doubling the heat flux to the center of the sample and the melt is established. The heaters are scrolled apart to spread the melt along the sample's length in both directions and the material resolidifies directionally behind the melt fronts. Since the resolidifying mass is suspended between two liquid zones, the transmission of vibrations and disturbances to the critical area is minimized and resolidification occurs in a containerless mode.

The SFZF is the result of a collaborative effort among Space Industries Inc., Calspan and the Los Alamos National Laboratory. Operation of the furnace has been used primarily for high temperature superconductor research.

Operational Characteristics

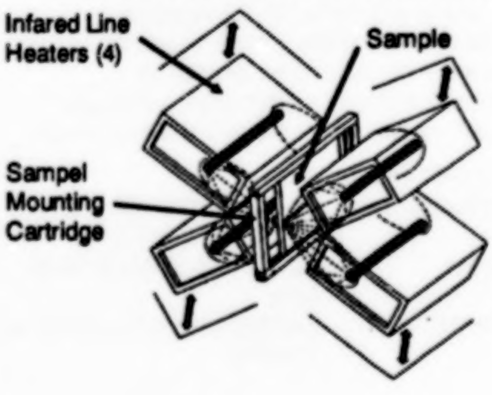
Approximately 1270 watts/cm^2 heat flux (controllable)
Heater translation rates from 0.06 to 5 cm/second (controllable)
Furnace walls maintained at less than 30° C
Various furnace purge gases

Sample Size:	(Generally a thin sheet) 0.1 in thick x 2.5 in W x 4.5 in L maximum

Carrier: Experimental aircraft, such as the KC-135

Available: Now

Contact: Wilson M. Fraser, Jr., Manager
Sheet Float Zone Furnace Program
Space Industries International, Inc.
711 West Bay Area Blvd., Suite 320
Webster, Texas 77598
(713) 338-2676, Fax (713) 338-2697



Single Axis Acoustic Levitator (SAAL)

Containerless processing may make possible the preparation of ultrapure glasses used in optical and electrical applications. Since some glasses require a melt temperature of up to 3,000° C, no unreactive containers are available on Earth as the container reacts with the melt, causing impurities. Acoustic processing on Earth is impossible because the sound waves cannot overcome gravity. The SAAL can levitate, melt at temperatures up to 1,500° C and resolidify glass samples acoustically.

Eight glass samples can be processed sequentially and automatically in the SAAL. The samples are positioned one at a time without wall contact in the furnace cavity by acoustic energy. The sample is then melted and cooled to solidification.

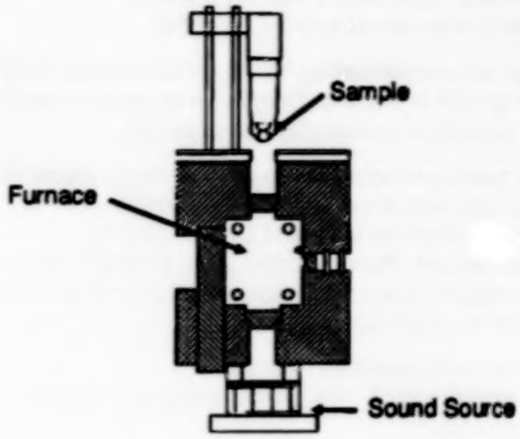
Operational Characteristics

Sample size:	4 to 10 mm spherical diameter
Operating temperature:	1,600° C
Furnace size:	93.50 cm H x 40.5 cm diameter
Furnace weight:	81.6 kg
Processing chamber:	10.2 cm x 10.2 cm x 11.4 cm

Carrier: Materials Science Laboratory (MSL)

Available: Now

Contact: NASA/Marshall Space Flight Center
Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-2728



Stabilized Electromagnetic Levitator (SEL)

The Stabilized Electromagnetic Levitator is a highly stable multi-coil levitator for melting and undercooling studies in the microgravity environment. It is characterized by independent control of heating and positioning. The SEL is a single-axis system powered by modified, commercially available, high efficiency, solid-state, radio frequency amplifiers. Both highly or poorly conductive materials, metallic or non-metallic, may be levitated. By varying the signals between coils, sample stability and oscillation can be controlled. Independent heating will allow undercooling without sample instability.

High frequency induction heating of samples to 2700° C or greater is possible. Samples may be processed in a vacuum or in controlled atmospheres.

The open architecture of the device allows access for diagnostic and process control equipment, such as noncontact temperature and optical property measurement. Precise temperature, surface tension and viscosity measurements would be possible in the stable quiescent sample.

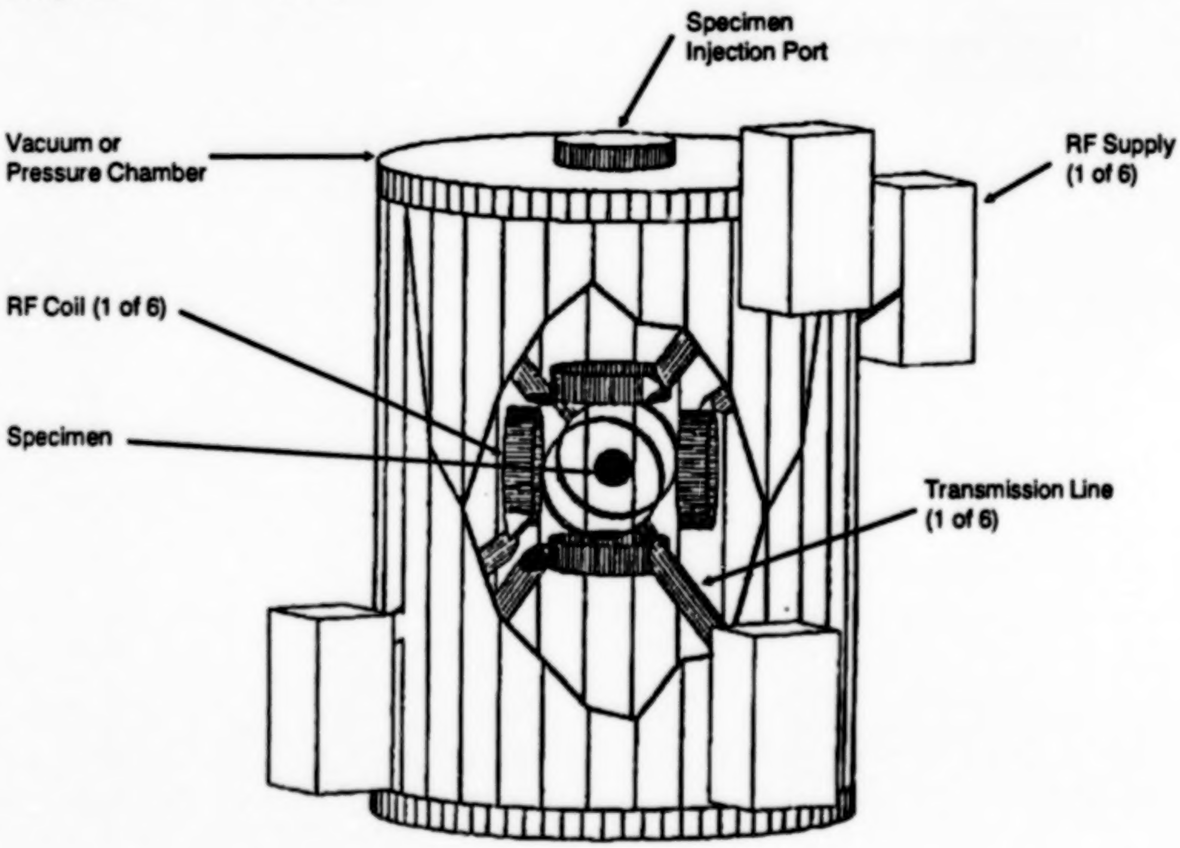
Tentative Capabilities

Temperatures*:	30° to 2700° C or higher
Isothermality*:	Good
Temperature Control Precision:	To be determined
Design Goal:	+/-5° C
Gas Purity and Particulate Contamination:	Excellent (as good as process gas)
Process Gas:	Vacuum, reactive or inert
Specimen Size:	2-6 mm
Specimen Motion:	+/-1 mm
Position Accuracy:	<+/-1 mm
Heating Rates*:	0° to 200° C/second or higher
Cooling Rates*:	0° to 200° C/second or higher
Spin Control:	Near zero or very low spin
Optical Access:	Versatile
Heaters:	Inductive heating
Supplemental Beam Heating:	Possible

**Dependent on sample properties and size*

Available: Now

Contact: Tom Danley
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Transparent Directional Solidification Furnace (TDSF)

The TDSF provides the capability to perform directional solidification experiments on transparent samples at relatively low temperatures. The furnace consists of slotted heating and cooling elements into which the sample is placed, in a rectangular transparent container. The heating and cooling is done with a pair of circulating constant temperature baths. The upper, heated portion of the furnace is separated from the lower, cooled portion with a slot through which the interface can be viewed. The furnace assembly is translated in order to move the interface through the sample.

Operational Characteristics

Oven temperature range:	Upper oven ambient to 150° C, Lower oven -20° to 20° C
Oven temperature accuracy:	+/-0.1° C
Oven translation speed:	720 mm/hr maximum
Oven step size:	100 nm
Optical magnification:	1X to 64X
Sample shape:	Rectangular
Sample size:	10 mm L x 10 mm W x 15 mm H

Carrier: Designed for ground-based research only (Microgravity Materials Science Laboratory)

Available: Now

Contact: Thomas K. Glasgow
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5014

Vapor Transport Furnace for Organic Crystals and Films

The vapor transport furnace is capable of operating on several experiment carriers on the Shuttle or on Space Station. The furnace consists of two concentric aluminum tubes with a vacuum space between them. A glass ampoule containing the chemicals for crystal growth is placed inside the inner aluminum tube. Special design considerations allow the furnace to operate at a 413° K (140° C) interior temperature with a power consumption of less than 2 watts when operated in a 293° K (20° C) environment. Gold coatings decrease the radiation heat transfer. A special support mechanism between the two aluminum tubes causes the heat transfer by conduction to be inconsequential. The design is versatile enough to allow its use in solution crystal growth, polymer reactions, melt growth and other applications in addition to vapor transport crystal growth.

Operational Characteristics

Size:	350 mm x 105 mm x 122 mm
Weight:	2 kg without controller
Power:	3 watts at 140° C
Operating temperature:	200° C maximum

Carrier: Get-Away-Special canister, experiment apparatus container, Shuttle middeck locker, middeck rack, Spacelab rack

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Zone Refining Furnace (ZoReF-1200)

ZoReF-1200 is a compact, adjustable temperature, zone-refining type furnace using a cylindrical design for melting and cooling materials in the microgravity environment. The device may have different applications for lower and higher temperature material processes. It is designed to be used with Deliverer-"X" and CHEOPS-"X" reentry recoverable vehicles. Samples may be preheated below the melting temperature to reduce the amount of time required for melting. Current furnace design utilizes passive cooling of the samples.

Operational Characteristics
Preheating and Melting

Zone Temperature:	**500° to 1200° C range**
Translation Speed:	**5 cm³/ <30 seconds**
No. of Samples:	Up to 10 different samples

Carrier: Deliverer-X and CHEOPS-X reentry vehicles

Available: Under development

Contact: COR Aerospace Corporation
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 6760-2474

Other Materials Processing Devices
(See also pages 98 and 161.)

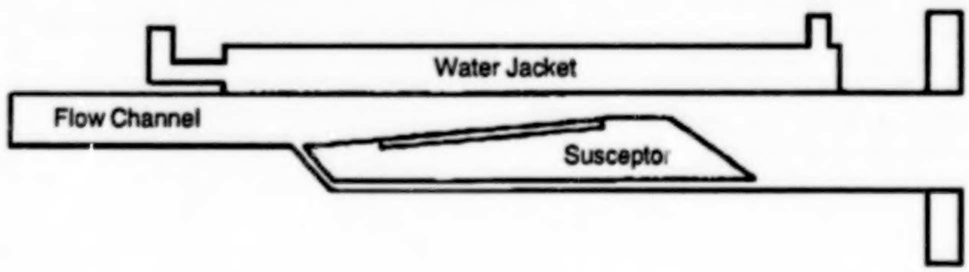
Chemical Vapor Deposition Facility (CVDF)

This facility is intended for flow characterization of chemical vapor deposition reactors in the microgravity environment. The plan is to demonstrate the CVDF for non-reacting flows and then determine the feasibility of fluorescent measurement techniques. The sample size is 50 cm^3.

Carrier: Cross-bay carrier in Shuttle cargo bay

Available: Ground-based facility (non-surfacing flares) is available. A flight unit is proposed.

Contact: I.O. Clark
NASA/Langley Research Center
Hampton, VA 23665
(804) 865-3777



Commercial Refrigerator/Incubator Module (C-R/IM)

The C-R/IM provides a low cost and easily integrated temperature-controlled storage volume for many types of experiment samples such as protein crystals, living cells, organisms and materials. The C-R/IM is an active unit with a temperature range from 4 to 40° C, within +/-0.5° C, with a set point adjustment to 0.1° C. The version shown, is designed to accommodate existing Vapor Diffusion Apparatus (VDA) trays for current crystal growth experiments. Other versions can be made available.

Operational Characteristics

Control temperature:	4° to 40° C
Nominal power:	100 W at 28 Vdc
Ambient Air:	18° to 35° C
Empty Weight:	14.5 kg
Payload Capacity:	17.3 kg (middeck)
Internal size:	25.7 cm W x 16.5 cm H x 37.1 cm D
External size:	46 cm W x 27 cm H x 54 cm D

(Replaces one standard middeck locker volume)

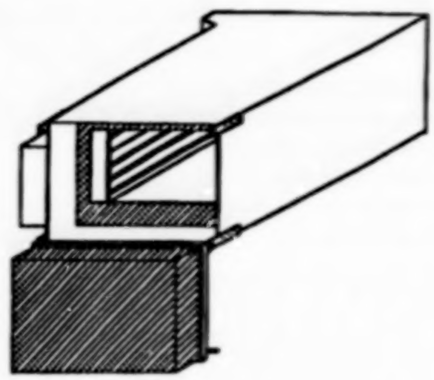
Set points:	every 0.1° C

Data Logger available

Carrier: Shuttle middeck

Available: Under development

Contact: Space Industries Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX, 77598-4001
(713) 338-2676



Critical Fluid Light Scattering Experiment Apparatus (CFLSE)

The highest temperature at which a gas can be liquified by pressure alone is called the critical temperature. However, due to the effect of gravity, the physical characteristics which have been described theoretically, as the critical temperature is approached, are difficult to observe.

The CFLSE measures the decay rates and correlation lengths of critical density fluctuations in Xenon, a nearly ideal model fluid, very near its liquid-vapor critical points, using laser light scattering and photon correlation spectroscopy. The fully automated system permits continuous operation for up to 100 hours of data collection. Temperatures will cover the range of 1° Kelvin to 100° microKelvin from the critical point.

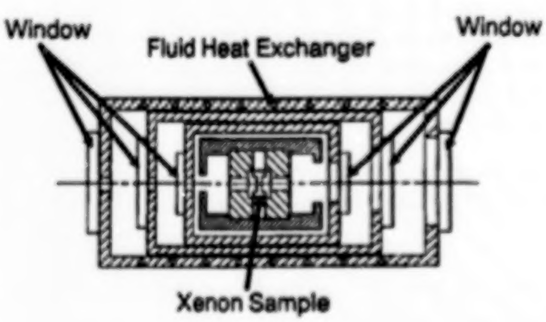
Operational Characteristics

Sample:	Xenon at approximately 57.6 atm
Sample size:	2 cm^3
Apparatus size-2 units:	0.9 m L x 0.6 m W x 0.45 m H 0.3 m L x 0.6 m W x 0.6 m H
Apparatus weight:	410 kg overall

Carrier: U.S. Microgravity Payload (USMP)

Available: 1991

Contact: Richard W. Lauver
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2860



Dendrite Growth Apparatus

This apparatus measures dendrite growth velocities, tip radii and side-branch spacing. Materials studied are organic; they serve as models for metal alloy dendrite growth. A material is melted and then supercooled to desired temperature, at which time the growth of a free dendrite is initiated at the tip of a capillary injector in the center of the growth chamber. Growth chamber is submerged in a thermostatic isothermal bath capable of maintaining temperatures within +/-0.002° C.

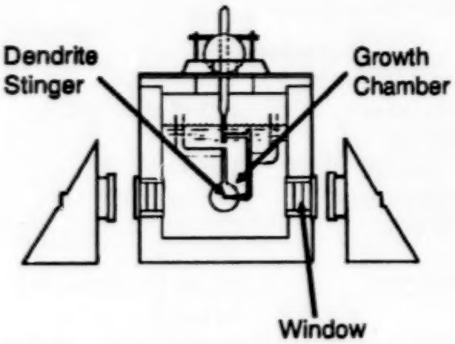
Operational Characteristics

Operating temperature:	4.0° to 80° C
Temperature accuracy:	+/-0.002° C
Photogenic resolution:	+5 micrometers
Sample capacity:	One growth chamber
Sample chamber size:	1 cm to 8 cm diameter

Carrier: Designed for ground-based research only (MMSL)

Available: Now

Contact: NASA/Lewis Research Center
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5013



Diffusive Mixing of Organic Solutions (DMOS) Apparatus

The 3M DMOS apparatus is used for crystal growth from solution, chemical reactions or fluid mixing experiments in the microgravity environment. Modifications are feasible to fit customized needs, i.e., quartz windows added for optical measurements.

The DMOS apparatus includes six independent, modular cells each having three 83-ml chambers separated by gate valves. The gate valves have a maximum 4.5 cm² open area. The experiment cells are fabricated from stainless steel and teflon-coated on the interior to provide a chemically inert environment. The flight-proven apparatus contains three levels of hermetic containment: this allows experimentation with hazardous materials while avoiding any hazard to the crew. The DMOS apparatus can be supported by the 3M Generic Electronics Module (GEM/2) which enhances payload control functions and provides data acquisition and crew interface.

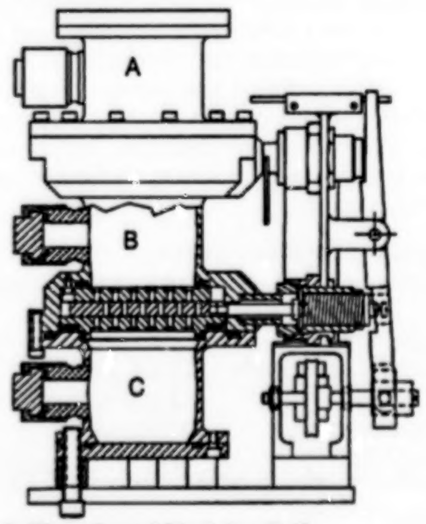
Operational Characteristics

Operating temperature:	Ambient to 45° C (higher temperatures possible with modifications)
Modular cell size:	13.7 cm x 17.3 cm x 22.3 cm
Total apparatus size:	Two middeck locker spaces
Modular cell power requirements:	5 W
Modular cell weight:	4.8 kg
Total apparatus weight:	60.6 kg with EAC

Carrier: The DMOS unit is housed within an Experiment Apparatus Container and can be mounted into the Shuttle middeck or cargo bay carriers, Spacelab or SPACEHAB facilities.

Available: Now

Contact: E. L. Cook
3M Space Research and Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



3-Chambered Modular Cell

Electrodeposition and Codeposition Apparatus

This system allows production of metal deposits and metal codeposits (composites) at controlled rates. A programmable microprocessor-controlled electronic unit powers the entire package. Thirteen cells are arranged in a bank. Each cell contains an electrolytic solution to sustain an electro-deposition process and produce metal coatings. Five of the cells are equipped with small stirring motors to agitate inert particles in the solution and produce metal composites. This process is recorded with a 35mm camera controlled by the unit electronics. The cells are operated at constant current or voltage. Current and voltage data are stored. Sampling rate is controlled by the unit software. The unit is thermally controlled.

Operational Characteristics

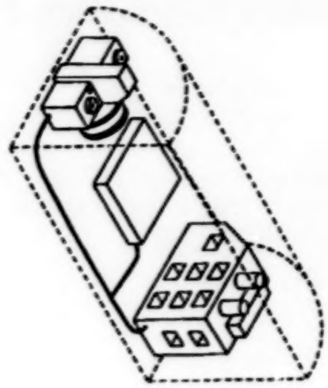
Size:	700 mm x 200 mm x 230 mm
Weight:	10 kg

Power: Approximately 20 watts to drive motors, cells, camera and flash

Carriers: KC-135 parabolic flights, Get-Away-Special canisters, sounding rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620



Fluid Science Module (FSM)

The Fluid Science Module is designed to house three experiments. Two of these experiments are intended for investigation of the Marangoni convection effect, where one will make use of thermocapillary drop motion under microgravity, and the other will study mass transfer from liquid to gas phase. Each of these experiments is monitored by a TV-system from which the pictures are transmitted to ground via an S-band Video Link. The third experiment is for study of thermal conductivity of liquids by means of a transient hot-wire technique under microgravity.

The Inner Experiment Mounting Structures is composed of two aluminum panels mounted along the module. In principle, each experiment is built on a panel which comprises self-contained units that can be assembled, handled and tested independently. However, the thermal conductivity experiment comprises two test cells that are mounted directly to the cylindrical structure wall.

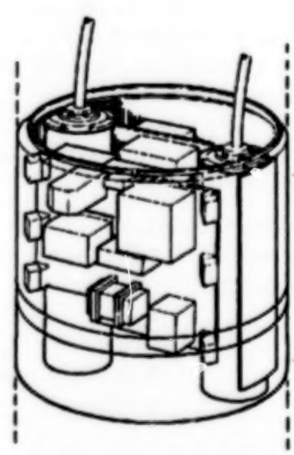
Operational Characteristics

Size:	390 mm L x 438 mm diameter
Weight:	38.6 kg
Material:	Outer structure – magnesium casting Inner structure – aluminum panels
Type of joints to neighboring modules:	Radax joints
G-force:	Approximately 14 g maximum
Thermal environment for the experiments:	13° to 23° C

Carrier: Sounding rockets

Available: Now

Contact: CONATEC, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088



Foam Formation Apparatus

A nitrogen cylinder actuates one of two piston/cylinder assemblies, injecting the contents of the first cylinder into the second. The contents of the second cylinder are then mixed by a motor-driven propeller. After a few seconds of stirring the mixture is expelled through a conical exit containing a screen. A 35 mm camera with flash attachments captures the foaming process. Mirrors on each side of the exit funnel allow a rear view. A thermistor mounted on the exit funnel records the temperature profile of the experiment.

Operational Characteristics
Size: 648 mm x 368 mm x 254 mm
Weight: 16.1 kg
Power: 2.1 Amps at 28 Vdc, approximately 20 watts power required to operate camera and flash
Gas operating pressure: 34 atm

Carrier: Sounding Rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Fourier Transform Infrared Spectrometer Apparatus

The 3M Fourier Transform Infrared Spectrometer is used for experimentation involving materials processing and studies of dynamic chemical systems in microgravity. Some examples of the many applications of the spectrometer for recording data are polymerization, melt crystallization and phase separation. The apparatus utilizes a Michaelson interferometer to provide a unique opportunity for recording, in real-time, the dynamic effects of microgravity on these chemical systems. In its current configuration, the apparatus provides 20 sample positions, can be thermally controlled up to 250° C and operates in the transmission mode. Modifications to the apparatus for accommodating alternate sample configurations are available. Interferograms can be acquired every 4 seconds and stored in the mass memory of an auxiliary computer, such as the 3M Generic Electronics Module (GEM/2), or transformed into IR spectra and displayed on-orbit.

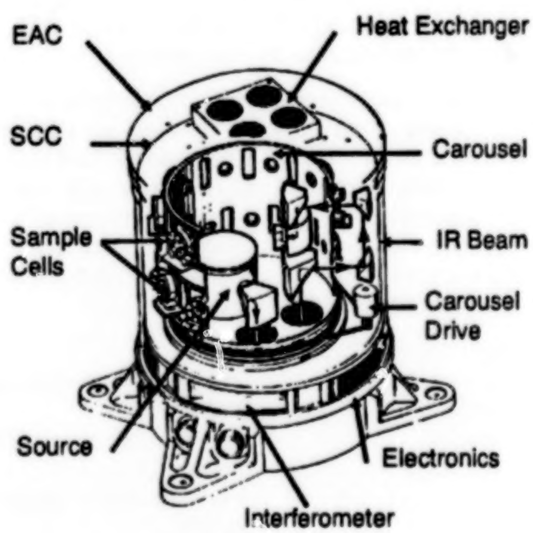
Operational Characteristics

Wavenumber range:	5,000 cm^{-1} to 400 cm^{-1}
Wavenumber precision:	0.01 cm^{-1}
Resolution:	4 cm^{-1}
Power:	110 W
Size:	2 middeck locker spaces
Weight:	54.5 kg

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: E. L. Cook, Director
3M Space Research and Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



Isothermal Dendritic Growth Experiment Apparatus (IDGE)

The IDGE allows investigators to measure dendritic growth in microgravity where heat transfer is a more dominant factor in crystallization than fluid motion; and to study the effects of melt supercooling and acceleration on dendritic growth rate, tip radius, side branch spacing and general morphology. The materials studied are transparent, crystalline organics such as pure succinoitrile (SCN) and SCN alloys. One sample is contained in an isothermal growth chamber, where it is melted, then cooled, and injected with a dendrite in the center. Twenty different supercool temperatures per flight are possible.

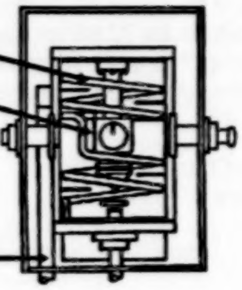
Operational Characteristics

Sample size:	4 cm to 6 cm diameter
Sample volume:	11 to 35 cm^3
Temperature range:	30° to 60° C
Apparatus size:	100 cm L x 86 cm W x 94 cm H
Apparatus weight:	Approximately 310 kg

Carrier: U.S. Microgravity Payload (USMP)

Available: Under development

Contact: Edward A. Winsa
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2861



Low Gravity Mixing Equipment

The low gravity mixing equipment can be used to mix liquid phase materials at room temperature in suborbital research applications. Up to four samples can be mixed on each of six possible parabolic trajectories per experiment. The complete experiment package, which consists of an upper containment chamber, sample vial rack, delivery lines, metering pump, electromagnetic pump, video camera and videocassette recorder, power/fuse box and associated support structures, is housed in an instrument rack. The experimenter has the flexibility to control the amount and timing of material delivered to the 4 ml sample vials, the frequency and amplitude of vibration and the timing of video recording needs.

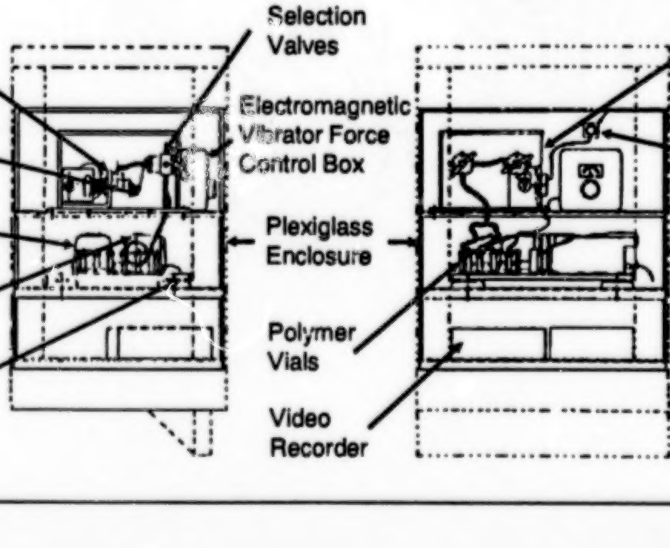
Operational Characteristics

Equipment size:	Housed in 61 cm L x 91 cm H x 53 cm D instrument rack
Mass:	85 kg
Sample size:	Up to 4 ml per vial
Modularity:	Can be adapted to experimenter's needs

Carrier: Suborbital research aircraft instrument rack

Available: Now

Contact: Advanced Materials Center/Battelle
505 King Avenue
Columbus, OH 43201-2693
(614) 424-6376 or (614) 424-4146



Low-Temperature Research Facility (LTRF)

The LTRF provides a capacity to conduct experiments that require temperatures as low as 1.5° K and acceleration forces of less than 10^{-4} g. The first two flights of the LTRF were planned to investigate the bulk properties of superfluid helium and the behavior of superfluid helium at the Lambda transition. Results will test the theories of cooperative phase transitions.

The cryostat of the LTRF accommodates a sample of 20.32 cm diameter by 73.66 cm length, with a weight limit of 31.50 kg. The experiment can be preprogrammed over a proposed 168-hour on-orbit lifetime.

Operational Characteristics

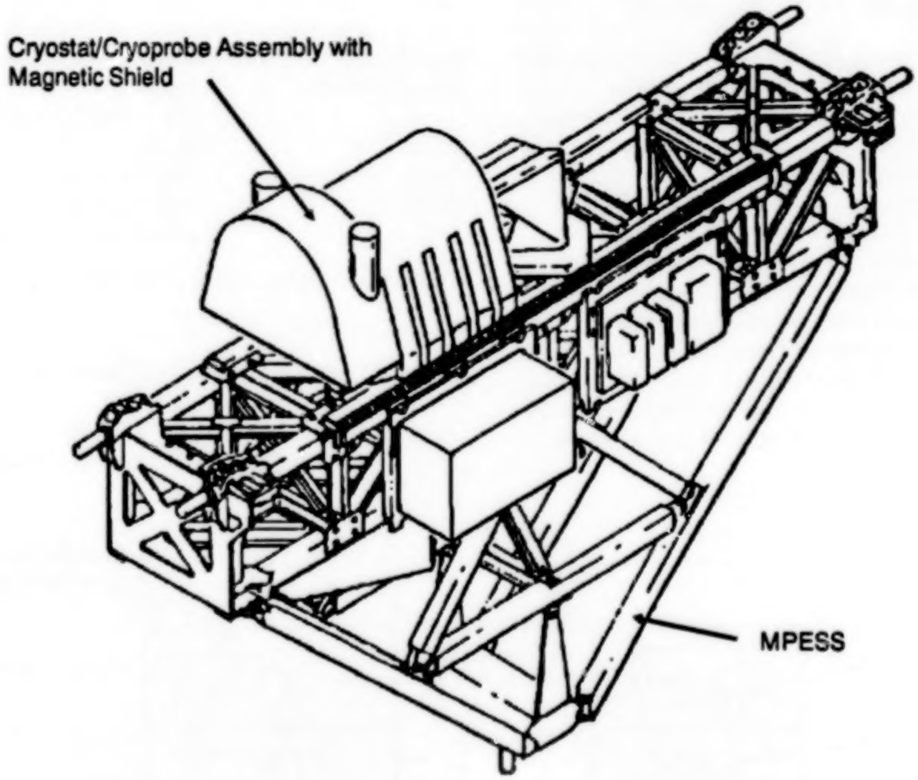
Apparatus size:

3 units:	137.16 cm L x 102.87 cm W x 86.36 cm H
	81.28 cm L x 60.96 cm W x 55.88 cm H
	45.72 cm L x 40.64 cm W x 20.32 cm H
Apparatus weight:	376.65 kg overall plus sample
Sample temperature range:	1.5° to 4.5° K

Carrier: Materials Science Laboratory (MSL)

Available: Now

Contact: NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-4818



Organic Separation

This apparatus consists basically of several glass cuvettes (1.5 ml) containing immiscible liquids and stirring bars that are spun by a small motor. The progress of demixing is then followed photographically. The block holding the cuvettes contains a heater and a thermistor for temperature control of the block. A camera photographs the 12 cuvettes which are back lit by a photo flash.

Operational Characteristics

Size:	457 x 178 x 170 mm
Weight:	6.5 kg
Power:	12 stirring motors require approx. 100 ma at 3 vdc each. Heater requires approx. 5 watts at 28 vdc. Power needed to operate camera and flash

Carrier: Shuttle, Get-Away-Special canister, sounding rockets, KC-135

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of ALabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Multipurpose Experiment Modules (TEM 06)

The TEM 06 modules are suitable for the implementation of experiments from almost any scientific discipline. The module consists of an experiment platform for mounting the experiment, power supply and the electronics package. The experiments are individually configured and installed in this module type. A number of standard components are available for setting up the experiments, including:

- Pneumatic-hydraulic assemblies for the movement of parts
- Electromotor assemblies to move and position experiment hardware
- Supporting devices for optical components
- Various cameras:
  - Film cameras (16 mm) with a picture frequency of up to 400 fps and time registration up to 1/100 second
  - Miniature camera
  - Video cameras applying the tube and CCD Techniques with the associated ground support equipment such as monitors, recorders and transparent overlay of data/text
- Specific experiment cells
- Optical diagnosis appliances such as:
  - Top view/transmitted light illumination
  - Schlieren optics
  - Laser optics with beam filtering for diffraction measurements
  - Laser light band optics
  - Differential interferometer
  - Microscope for transmitted light phase contrast or dark field with remote-controlled focusing
- Pressure sensors, temperature sensors and position sensors
- Control and measurement electronics
- Data acquisition: 32 or 64 analog channels, 10 bits, 4 Hz standard; for rapid processes up to some TBD kHz.

Standard Power System

Electronic:	NiCad 28 Vdc/2.5 Ah Extension to 2 x 28 Vdc/ 2.5 Ah is possible

PCM System: 32 analog channels, 0 to 5 V, 10 bit
Extension to 64 channels possible
30 digital channels, 0/1 event status bits
Extension to 60 channels possible

Timer: 16 independent events
Extension to 2 x 16 events possible

External/Internal Switch: 1 unit for electronic
Extension for 2 units possible

Module TEM 06-9
This module (of the TEM 06 series) is designed to investigate a variety of experiments in the fluid dynamics area. It is applicable to the investigation of the establishment of a floating zone with silicon oil. The primary experiment chamber contains an integrated fluid storage system which may be used to enhance the experiment performance in a variety of applications. The goal is to observe the process of zone establishment using different velocities and the oscillation of the zone during the process. The chamber is illuminated by field illumination and the process is recorded by 16-mm color film camera.

Multipurpose Experiment Modules (continued)

Module length:	679 mm
Module weight:	45.0 kg

Carrier: Shuttle middeck

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Reaction Injection Molding (RIM) Apparatus

RIM is a polymer process in which stoichiometric proportions of liquid monomers or oligomers are mixed intensively by impingement, then injected into a mold where polymerization commences. RIM can also be referred to as reaction injection chemistry (RIC) since this apparatus can accommodate a wide variety of reactive chemistries. The unit also can be used to conduct other experiments, such as polymer blends.

The basic operation of the RIM system is initiated by pressurizing each of two reactants which are then guided to one of four mixing heads, where mixing occurs by impingement. Molecular level observations and chemical kinetics of the ensuing polymerization can be achieved in real-time when the RIM system is interfaced with the 3M Fourier Transform Infrared Spectrometer (FTIR).

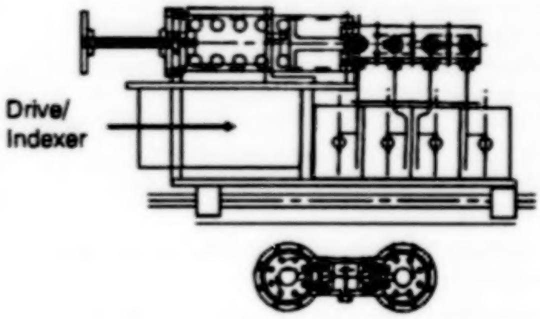
Operational Characteristics

Pressure:	0 to 2,000 psi
Temperature:	Ambient to 175° C (higher temperatures possible with modifications)
Weight:	15 kg to 18 kg
Size:	0.03 m^3
Capacity:	1 ml to 70 ml

Carrier: This unit is designed for use in the KC-135 aircraft; modifications are underway for use in the Shuttle middeck or cargo bay carriers (Spacelab or SPACEHAB).

Available: Now

Contact: E. L. Cook
3M Space Research and
Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



Rigid Gas-Permeable Plastic Material

The purpose of this development is to investigate the possibilities of producing an improved, rigid, gas-permeable plastic material for contact lenses by polymerization in zero-g. Polymerization should result in more uniform polymer matrix for enhanced permeability. This material can then be used in extended-wear contact lenses and lenses for pilots and astronauts.

Carrier: Shuttle middeck experiment

Available: Under development

Contact: B.T. Upchurch
NASA/Langley Research Center
Hampton, VA 23665

Solid Surface Combustion Experiment Apparatus (SSCE)

The SSCE will investigate mechanisms that control flame spreading on solid fuel surfaces to improve the understanding of material flammability and burning characteristics. In the SSCE, thermally-thin fuel samples (e.g, ashless filter paper) and thermally-thick fuel samples (e.g., polymethyl-methacrylate) are ignited and burned in a sealed chamber. This permits the study of the processes that influence the vapor phase of solid fuel combustion in the absence of buoyant or forced gas-phase flow.

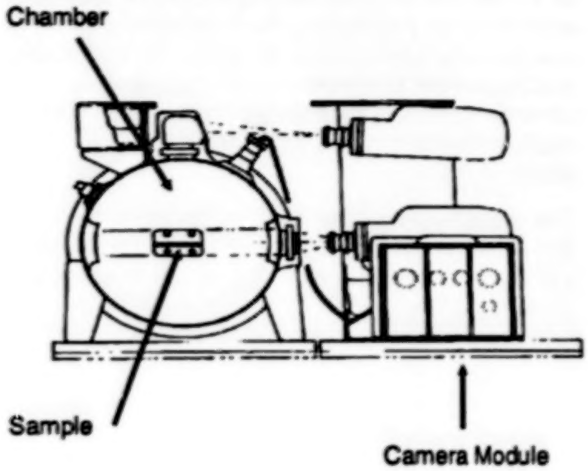
Operational Characteristics
Sample size

Thermally-thick fuel:	0.18 cm x 3.0 cm x 11.1 cm
Thermally-thin fuel:	0.315 cm x 0.630 cm x 2.000 cm
Oxidizer (air):	35%, 50% and 70% O_2
Overall dimensions:	55.6 cm L x 93 cm W x 53.5 cm H
Chamber dimensions:	51.3 cm x 34.3 cm ID
Weight-overall:	55 kg

Carrier: Shuttle middeck

Available: Now

Contact: John M. Koudelka
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2852



Surface Tension-Driven Convection Experiment Apparatus (STDCE)

Experiments conducted in the STDCE will enhance the study of transient and steady state thermocapillary flows in fluids. These flows result from the variations of surface tension with surface temperature. Oscillations in the velocity of thermocapillary flows may have deleterious effects on solidification, crystal growth and containerless processing in space. The data obtained from this experiment will verify mathematical modeling and allow investigators to complete the numerical model. This will lead to improved crystal growth and solidification processing techniques.

The STDCE consists of a circular container filled on-orbit with silicone oil producing a flat free surface. The oil is heated at the surface with a CO_2 laser or internally with a submerged cartridge. Surface temperatures are measured with a scanning IR imager. Particles in the oil are illuminated with a laser diode light sheet and velocities measured by computer analysis of video tape.

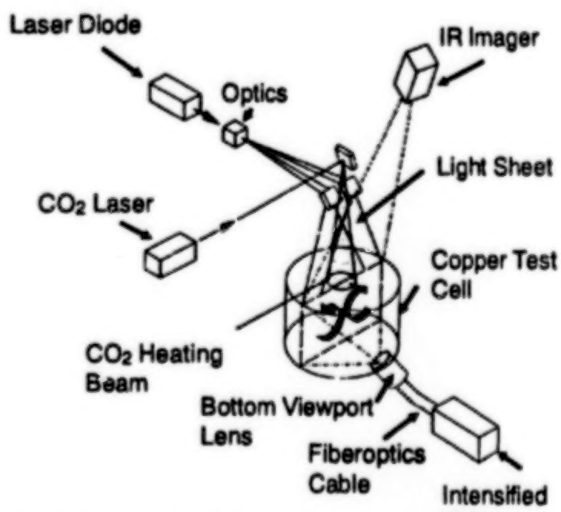
Operational Characteristics

Sample:	10 cs silicone oil
Sample volume:	400 ml
Sample chamber:	5 cm H x 10 cm diameter
Temperature range:	10° to 65° C (delta)
Apparatus size:	50 cm L x 50 cm W x 100 cm H
Apparatus weight:	227 kg overall

Carrier: Spacelab-Double Rack

Available: Under development

Contact: Thomas P. Jacobson
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2872



Surface Tension-Driven Convection Experiment Concept

Thin-Film Reactor System

The thin-film reactor system was developed to investigate thin films of thermosetting resins containing a rubber-dispersed phase under low gravity conditions. The basic unit of the thin-film reactor is a digital timer and sequence controller to be controlled independently with regard to sequence and event duration. Additionally, there are several solenoids and positive stops to control the motion and position of events during the experiment: an ultraviolet source, a temperature-process controller and heating coil, a mixing motor and a chamber rotational motor.

The operating procedure involves removal of the thin-film ring from the mixing chamber and curing the sample, shutting down the mixing motor, rotating the process chamber to the post-cure chamber and lowering the ring into the post-cure chamber.

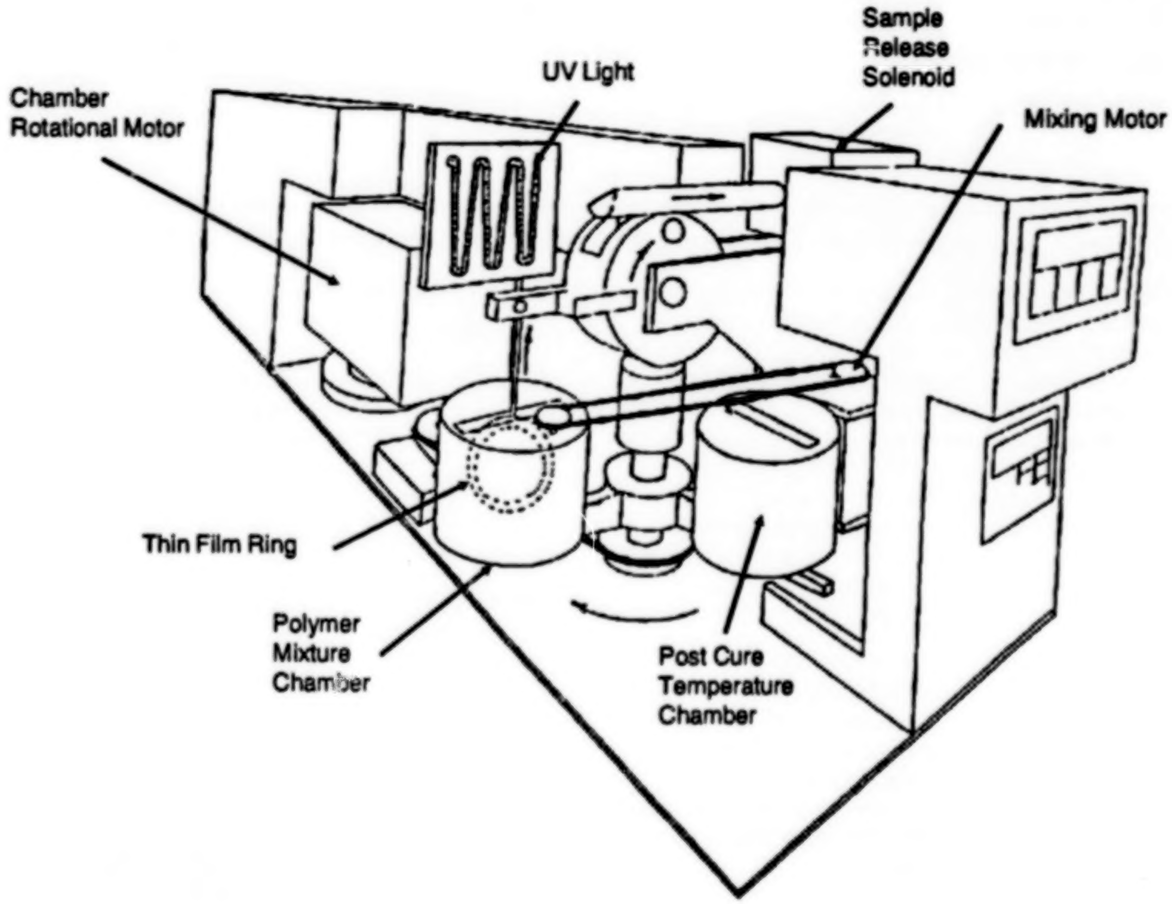
Operational Characteristics

Size:	76 cm L x 36 cm W x 46 cm H
Weight:	50 kg
Modularity:	Experiment can be adapted to experimenter's needs

Carrier: Drop towers; could be modified for suborbital aircraft testing

Available: Now

Contact: Advanced Materials Center/Battelle
505 King Avenue
Columbus, OH 43201
(614) 424-6376 or (614) 424-4146



Life Sciences/Biotechnology

In addition to materials processes, the microgravity environment is helping us to advance our knowledge of how living systems function. Gravitational biology research focuses on determining how the near weightlessness of space affects both plant and animal species from fertilization through birth, maturation and death; we need this knowledge not only to increase our understanding of terrestrial life, but also in preparation for future long-term journeys and habitation in space.

Space offers a unique materials processing environment because it provides microgravity and also near-zero temperatures, a high vacuum, a sterile environment, and heat and solar energy from sunlight. Space-based biotechnology takes advantage of these characteristics to produce protein crystals and purer and more potent drugs such as isoenzymes and antibiotics. Materials separation, for example, utilizes processes such as electrophoresis, isoelectric focusing and suspension cell culturing to produce pharmaceutical products with greater efficiency and higher purity. Crystals up to a hundred times larger than those produced on Earth can be made in microgravity by using various processes such as floating zone, vapor crystal growth and liquid crystal growth.

Equipment for life sciences and biotechnology experiments share a large inventory as a result of the ongoing human and non-human research developed for the Shuttle and Spacelab programs. Some of the entries that follow deal with investigations not necessarily involving a human or primate subject and therefore may be of interest to commercial developers exploring other related areas. In low gravity, the influences of thermal turbulence, buoyancy and sedimentation are reduced, much to the advantage of investigations exploring protein crystal growth, the separation of biological materials and cell culture.

Biotechnology

Automated Generic Bioprocessing Apparatus (AGBA)

The AGBA was developed as a tool to study a variety of biomaterials processes in reduced gravity. In the configuration flown on the Consort-3 sounding rocket in 1990, the payload weighed 40 pounds, occupied 1.1 ft^3 and processed 120 individual samples.

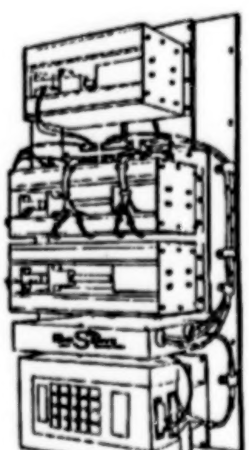
Fluid samples are stored in misaligned wells machined into six sets of polycarbonate blocks. Each set of blocks consists of a fixed and sliding part, housing from 12 to 28 sets of sample wells. Each set of sample wells consists of three wells with process precursor, initiator and terminator materials, respectively. During operation, the precursor and initiator materials are brought into contact and allowed to mix through diffusion during the microgravity episode. At the completion of the experiment, processed materials are brought into contact with the terminator materials.

Temperature can be controlled above ambient for some of the samples. Thermistors are used to record temperature during and after flight. In addition, 32 sets of samples are instrumented with LED's and photocells for recording of optical density changes in real time. Data are stored in the AGBA and telemetered to the ground.

Carrier: Sounding rocket

Available: Now

Contact: BioServe Space Technologies
University of Colorado
Campus Box 429
Boulder, CO 80309
(303) 492-1005



BioModule, PSU

The PSU BioModule can be used to study any reaction requiring instantaneous mixing to initiate a process of interest. Its uses include study of biological systems as well as chemical reactions. Simple modifications can be made to allow study of diffusion processes, such as crystal growth.

The BioModule provides simple and reliable addition of two separate fluids to a main chamber. Fluid transfer from reservoirs (up to 150 microliters) to the main chamber (300 microliters) is accomplished via mechanical pressure on a T-shaped silicone bag network with time of transfer during the flight under computer control. The BioModule unit contains separate silicone T's. These basic units can be reconfigured to satisfy new payload requirements.

In the current model, four BioModule units, with auxiliary electronics and on-board computer, fit into a space 9 in x 11 in x 13 inches and weigh less than 14 pounds. Firing each solenoid for mixing consumes about 2 amp for 0.2 second. The BioModule is scheduled to be aboard a Consort or Joust rocket mission once every six months. The Consort flights provide about seven minutes of microgravity. The Joust flights provide 15 minutes. Using this equipment, commercial clients can have samples go from their laboratory to space in about 18 hours. A new late-access policy on Consort missions allows biological samples to be placed on board just three hours before launch.

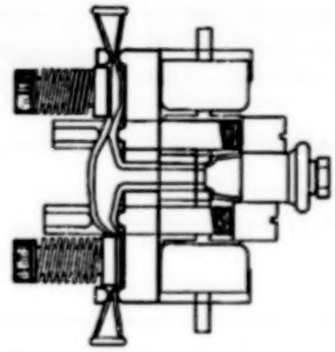
Operational Characteristics

BioModule size:	2 in x 6 in x 2 in
BioModule weight:	1.5 lbs
Power requirements:	2 amp for 0.2 seconds per solenoid
Reservoir size:	Up to 150 microliters
Main chamber size	300 microliters

Carrier: Sounding rocket, Shuttle, ELV

Available: Now

Contact: Roy Hammerstedt
Center for Cell Research
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407



Continuous Flow Electrophoresis System (CFES)

The CFES apparatus separates and purifies living cells and macro-modules without the gravity-induced influences of thermal convection and sedimentation. Processing of cells and proteins in the CFES indicate that biological substances can be separated into pure forms in space in large quantities; the CFES can separate over 400 times the quantity of material separated on the ground.

The samples of biological material are injected into a buffer solution that flows through an electrical field in the electrophoretic chamber. The product of interest is collected in the Fluid System Module (FSM) and returned to Earth. The CFES processes one large 2-liter volume sample for a period of up to 3 hours.

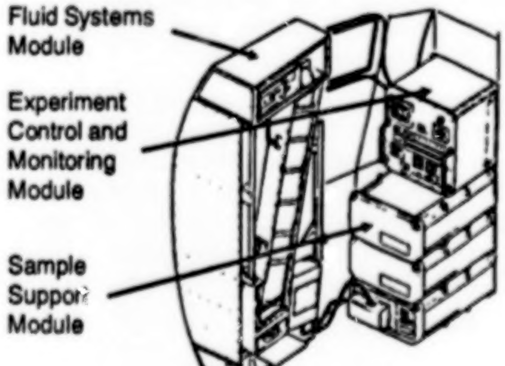
Operational Characteristics

Operating temperature:	12° to 16° C gradient
FSM Size:	76.2 cm L x 65 cm W x 201.7 cm H
Support equipment:	48.9 cm L x 49.1 cm W x 27.9 cm H
Apparatus weight:	371.47 kg overall

Carrier: Shuttle middeck

Available: Now

Contact: Wesley C. Hymer
Center for Cell Research
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407



Experiment R/IM Carrier (ISERC) and Power Supply/Controller

The ISERC payload carrier and power supply/controller, designed to fit inside the Refrigerator/Incubator Module (RIM), provides a structural, thermal interface for NASA's R/IM for user provided payloads. Developed for ITA's Material Dispersion Apparatus (see page 96), the carrier and power supply/controller can accommodate many middeck experiment payloads requiring a constant thermal environment, or can be redesigned to meet specific payload requirements. Payload elements are integrated with the carrier and power supply/controller. The carrier is then installed in the R/IM for integration with the Shuttle middeck. Both the carrier and power supply/controller have been tested and shown to meet the Shuttle vibration environmental specification.

Operational Characteristics

Carrier weight:	5.5 lbs
Allowable payload dimensions/volume:	10.00 in W x 6.22 in H x 14.25 in D/.513 ft^3
Power supply:	16.8 Vdc, 90 watt hrs (zinc air cells)
Power supply/controller mass:	2.5 lbs
Power supply/controller dimensions/volume:	5.0 in W x 3.38 in H x 3.9 in D/.038 ft^3

Carrier: Shuttle middeck R/IM

Available: Now

Contact: Jaak Holemans
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569

Fluids Experiments Apparatus (FEA)

The FEA is designed to provide the industrial user with a convenient, low-cost, modular experiment system for fundamental space-processing research in biology, chemistry and physics. With the FEA, investigators can conduct basic and applied processing or product development experiments in general liquid chemistry, crystal growth, fluid mechanics and thermodynamics, and cell culturing of biological materials and living organisms.

This general-use, adaptable facility can be configured to manipulate a wide variety of experiments including gaseous, liquid or solid samples, expose samples to vacuum conditions, and heat and cool samples. A number of specialized subsystems are planned for the FEA, including low- and high-temperature furnaces, custom-designed heaters, special sample containers and a specimen centrifuge. These modules will allow FEA hardware and operations to be customized to support a wide range of experiment requirements.

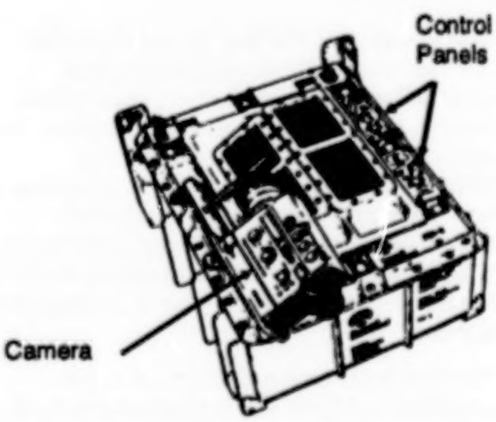
Operational Characteristics

Sample capacity:	Depends on sample
Apparatus size:	47.2 cm L x 36.8 cm W x 18.8 cm H
Weight:	11.7 kg

Carrier: Shuttle middeck locker

Available: Now

Contact: Michael J. Martin
Microgravity Projects FC25
Rockwell International
12214 Lakewood Boulevard
Downey, CA 90241



Generic Bioprocessing Apparatus(GBA)

The Generic Bioprocessing Apparatus (GBA) is a self-contained enclosure module designed to support experiments in microgravity. The GBA occupies the space of one middeck locker and will support payloads up to 2 ft^3 in volume and 40 pounds in weight. The inherent features of the GBA include: total access to the payload volume through the slide drawer design, data acquisition and control module (DACP), RS232 communication to the Shuttle grid, user defined from panel for experiment control and video downlink capability. Optional power packs also are available to supplement the standard 28 Vdc Shuttle power supply.

Operational Characteristics

Size:	One middeck locker
Payload size:	2 ft^3 volume and 40 lbs weight

Carrier: Shuttle middeck locker

Available: Now

Contact: BioServe Space Technologies
University of Colorado
Campus Box 429
Boulder, CO 80309
(303) 492-1005

Materials Dispersion Apparatus (MDA) Minilab

The Materials Dispersion Apparatus (MDA) Minilab is a lightweight device specifically engineered for materials processing such as protein crystals, thin film membranes, biomedical materials and others. The MDA operates on the principles of liquid-to-liquid diffusion and vapor diffusion (osmotic dewatering). The MDA is capable of automatically mixing up to 150 separate samples of virtually any two, three or four fluids in space and each test well cavity can accommodate fluid samples in the 50 to 400 microliter range. Multiple data points can be obtained on a single Shuttle, sounding rocket or ELV/satellite recovery capsule flight.

The MDA operates on the following principle: Two blocks of inert material each with a compatible number of test wells in the upper and lower half are held together in a lightweight aluminum housing. The test wells are misaligned prior to launch, thus separating the fluids to be mixed. After microgravity is achieved, the blocks are moved into alignment allowing the fluids to contact. An option exists to mix a third fluid to fix the process prior to reentry and/or to cast thin film membranes while still in the microgravity environment.

The MDA has flown on the Consort 1, 2 and 3 Sounding Rocket Flights and is manifested to fly on the Shuttle.

Operational Characteristics

Size:	3.3 in x 2.4 in x 10 in
Weight:	4.0 lb
Volume:	0.047 ft^3
Voltage:	16 Vdc
Power:	Two 3 watt/5 second pulses provided externally or with ITA's MDA controller and power supply
Nominal test wells:	140
Nominal test well capacity:	100 microliters

Carrier: Middeck lockers, sounding rockets, COMET recovery capsule, GAS cans, Hitchhiker, Spacelab, Spacehab and ITA Standardized Experiment Modules (ISEM's)

Available: Now

Contact: John M. Cassanto
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569

Matrix Reinforced Payload Process Method and Device (MaRP Process)

MaRP is a process method and device designed for protecting sensitive materials that are processed in the microgravity environment. Applications include, but are not limited to, biological materials such as proteins or other crystals, thin films and cellular structures. This process method is carried out subsequent to the completion of the materials process to protect the materials both for recovery in reentry vehicles and subsequent transport to a given location for analysis.

The Matrix Reinforced Payload Process is initiated following completion of the processing of the materials in Low Earth Orbit. The sample is encased in a small volume of an inert polymer matrix which protects it from g-loading and other vibrational forces. The payload, which is contained in Deliverer-"X" or CHEOPS-"X" reentry vehicle, is de-orbited, recovered and transported to a given location for subsequent analysis.

The device is a simple slow-flow injection system which delivers an uncured polymer matrix to the sample (e.g. a protein crystal). The inert polymer matrix then cures at a rate defined by the concentration of the curing agent and temperature of the process (4° C to 50° C), encasing the sensitive material. The polymer matrix can be removed to extract the sample for subsequent analysis in the Earth-based laboratory.

Carrier: Deliverer-"X" or CHEOPS-"X" reentry vehicle

Available: Now

Contact: COR Aerospace
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 676-2474

Phase Partitioning Experiment Apparatus (PPE)

The PPE measures the spontaneous demixing of liquid-liquid, aqueous polymer two-phase systems. Two-phase separation is universally used to separate biological cells and proteins. PPE permits the study of altering volume ratios, viscosity, interfacial tension, interfacial bulk phase potential, phase composition on the kinetics of demixing and the effects of chamber geometry, materials and wall coating of the foregoing parameters.

The PPE is configured to study natural coalescence and surface tension, two methods of phase separation. It also allows variations in interfacial tension, phase volume ratio, phase system composition and added particles. Up to 24 separate cavities can be filled with small quantities of two different polymers in simple water/salt solutions. The apparatus is shaken and photographed to record phase separation.

Operational Characteristics

Sample chamber:	1.4 cm L x 1.4 cm W x 1.4 cm H
Assembly size:	14.0 cm L x 3.3 cm W x 9.0 cm H
Assembly weight:	0.7 kg
Assembly volume:	526.7 cm^3

Carrier: Shuttle middeck locker

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-2728